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EVALUATION OF PEST MANAGEMENT PROGRAMS FOR COTTON, PEANUTS AND TOBACCO IN THE UNITED STATES

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RvR Consultants

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FINAL REPORT
OCTOBER, 1975

CONTRACT NO. EQ4AC036
RVR PROJECT NO. 66

FOR

COUNCIL ON ENVIRONMENTAL QUALITY
722 JACKSON PLACE, N.W.
WASHINGTON, D. C. 20006

AND

U.S. ENVIRONMENTAL PROTECTION AGENCY
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EVALUATION OF PEST MANAGEMENT PROGRAMS FOR COTTON, PEANUTS AND TOBACCO IN THE UNITED STATES

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FINAL REPORT
October 1975

Contract No. EQ4AC036
RvR Project No. 66

For

Council on Environmental Quality
Att.: Dr. Warren R. Muir

and

U.S. Environmental Protection Agency
Office of Pesticide Programs
Att.: Mr. C. D. Reese

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Pest management programs - 19 cotton in Ala., Arkl, La., Miss., N.C., Okla., and Texas; 3 peanut in Okla. and Tex.; and 3 tobacco in N.C. - were evaluated re users, locations, and characteristics; program costs; effects on crop yield; pesticide use; production costs; and growers' profits. The environmental impact and the biological and economic feasibility of each program were studied, and the constraints on the expansion of pest management programs and the applicability of the findings of this study to other crops were assessed. Regional reports containing detailed information on the programs studied, are included as appendices.

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PREFACE

This report describes the results of an "Evaluation of Pest Management Programs on Cotton, Peanuts and Tobacco in the United States" performed for the Council on Environmental Quality and the U.S. Environmental Protection Agency, Office of Pesticide Programs, under Contract No. EQ4AC036, RvR Consultants Project No. 66.

The project has been directed by Dr. R. von Rümker, Managing Partner, RvR Consultants, who also served as principal investigator. Co-principal investigators were Dr. G. A. Carlson, North Carolina State University; Dr. R. D. Lacewell, Texas A & M University; Dr. R. B. Norgaard, University of California; and Dr. D. W. Parvin, Jr., Mississippi State University. Dr. V. Ulrich, West Virginia University, assisted in finalizing this report. Ms. Freda Horay, RvR Partner, served as project associate. The field work was performed during the period July to September, 1974.

Dr. Warren R. Muir was project officer for the Council on Environmental Quality, and Mr. Charles D. Reese and Mr. Jeff Kempter represented the Office of Pesticide Programs, U.S. Environmental Protection Agency.

RvR CONSULTANTS

By Rosmarie v Rümker

Dr. Rosmarie von Rümker
Managing Partner
Project Manager

28 October 1975

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This study received much support, assistance and encouragement from many scientists and others knowledgeable in the subject area, including Dr. P. L. Adkisson, Dr. F. S. Arant, Dr. J. R. Brazzel, Dr. L. A. Falcon, Dr. J. M. Good, Dr. F. A. Harris, Dr. J. B. Kendrick, Jr., Dr. F. G. Maxwell, Dr. L. D. Newsom, Dr. R. F. Smith, and Dr. R. V. Sturgeon, Jr. In addition, a number of persons were particularly helpful to the regional studies and in reviewing the regional report drafts, as recognized in the regional reports.

Draft final reports on the study were reviewed, in whole or in part, by Dr. W. R. Muir, Mr. C. D. Reese, Mr. J. Kempter, Dr. V. Ulrich, Dr. F. G. Maxwell, Dr. D. Pimentel, Dr. J. M. Good, Dr. V. W. Davis, and Dr. J. R. Brazzel. Many constructive comments that were very helpful in the finalization of this report were received from these reviewers.

The authors express their sincere gratitude for all of these contributions.

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D. W. Parvin, Jr.

October, 1975

TABLE OF CONTENTS

Page

Introduction 1

Objectives 2

Study Approach and Methods 3

Summary 7

Conclusions and Recommendations 12

Development of Pest Management Programs in the U.S. 17

Environmental Effects of Pest Management Programs 21
  Human Health Effects 22
  Environmental Effects 24

Feasibility of the Pest Management Programs Studied 27

Constraints on Expansion of Pest Management Programs 32
  Research 35
  Development 36
  Pest Management Delivery Systems 38
  Interdisciplinary Research, Education and Training of Personnel 40
  Program Management 41

Applicability of Findings to Other Crops 43

Cotton Pest Management Programs 47

  Background 47

  Trends in Cotton Production and Pesticide Use 47

  Users, Locations and Characteristics of the Programs Studied 49

  Program Costs 61

  Program Effectiveness 67
    Effects on yield 70
    Effects on insecticide use 70
    Effects on production costs 71
    Effects on growers' profits 71

  Constraints on Expansion of Cotton Pest Management Programs 73

Peanut Pest Management Programs 76

  Background 76

  Trends in Peanut Production and Pesticide Use 77

TABLE OF CONTENTS

Page

Users, Location and Characteristics of the Programs Studied 79

Program Costs 83

Program Effectiveness 86
  Effects on yield 86
  Effects on pesticide use 89
  Effects on production costs 90
  Effects on growers' profits 90

Tobacco Pest Management Programs 93

Background 93

Trends in Tobacco Production and Pesticide Use 93

Users, Locations and Characteristics of the Programs Studied 96

Program Costs 99

Program Effectiveness 100
  Effects on yield 101
  Effects on pesticide use 102
  Effects on production costs 102
  Effects on growers' profits 103
  Effects on tobacco sucker control and stalk destruction 103

References 105

Appendix A - Evaluation of Pest Management Programs for Cotton in Mississippi, Alabama and Louisiana . A-1 to 65

Appendix B - Evaluation of Pest Management Programs for Cotton in North Carolina and Arkansas . . . . B-1 to 58

Appendix C - Evaluation of Pest Management Programs for Cotton in California and Arizona . . . . C-1 to 59

Appendix D - Evaluation of Pest Management Programs for Cotton in Texas . . . . D-1 to 203

Appendix E - Evaluation of Pest Management Programs for Peanuts in Texas and Oklahoma . . . . E-1 to 63

Appendix F - Evaluation of the Pest Management Program for Tobacco in North Carolina . . . . . . F-1 to 36

LIST OF TABLES

Table Page

1 Benefits of Pest Management Programs on Cotton, Peanuts and Tobacco 9

2 U.S. Cotton Acreage, Insecticide Use on Cotton, and Production of Insecticides 48

3 Characteristics, Costs and Benefits of 19 Cotton Pest Management Programs 52-56

4 Estimated Implementation and Operating Costs for Regional Pest Management Programs on Cotton in Texas 64

5 Comparison of Scouting Costs vs. Costs of Supervision and Overhead for Selected Cotton Pest Management Programs 65

6 U.S. Peanut Acreage and Use of Insecticides, Fungicides and Herbicides on Peanuts 78

7 Characteristics, Costs and Benefits of 3 Peanut Pest Management Programs 81

8 U.S. Tobacco Acreage and Use of Pesticides on Tobacco 95

9 Characteristics, Costs and Benefits of the North Carolina Tobacco Pest Management Programs 98

LIST OF FIGURES

Figure Page

1 Locations of the Cotton Pest Management Programs . . . 51

2 Locations of the Peanut Pest Management Programs . . . 80

3 Locations of the Tobacco Pest Management Programs . . 97

INTRODUCTION

Much has been written and said about integrated pest management (IPM) in recent years, and several definitions have been offered by a number of authors and speakers including Geier (1966); Smith and Reynolds (1966); Smith and van den Bosch (1967); Stern et al. (1959); Kennedy (1968) Falcon (1972); and Rabb (1972). The Council on Environmental Quality (1972) defines integrated pest management as follows:

> "Integrated pest management is an approach that employs a combination of techniques to control the wide variety of potential pests that may threaten crops. It involves maximum reliance on natural pest population controls, along with a combination of techniques that may contribute to suppression--cultural methods, pest-specific diseases, resistant crop varieties, sterile insects, attractants, augmentation of parasites or predators, or chemical pesticides as needed. A pest management system is not simply biological control or the use of any single technique. Rather, it is an integrated and comprehensive approach to the use of various control methods that takes into account the role of all kinds of pests in their environment, possible interrelationships among the pests, and other factors."

For purposes of this study, pest management programs have been defined as those programs that contain at least the following three elements:

(1) Diagnosis of the pest problem by scouting, also referred to as "field checking", pest trapping and/or other methods;

(2) Determination if and when intervention, i.e., pest suppression, is required, mostly based on damage thresholds;

(3) Suppression of the pest(s) by the most appropriate tool(s) available.

The determination if and when intervention (pest suppression) is required is usually based on so-called "economic damage threshold" infestation levels. Up to the present, the most frequently used method of intervention (pest suppression or control) has been the use of chemical pesticides.

Unilateral reliance on chemical pesticides has resulted in economically as well as ecologically disastrous failures in a number of agro-ecosystems (Adkisson, 1971; Smith, 1962; Smith and Reynolds, 1972). On a number of crops, including cotton, deciduous fruits, vegetables, and others, insect and/or mite pests have become increasingly more difficult to control with chemical pesticides due to the development of resistance, destruction of beneficial predators and parasites, rapid resurgence of target pests, and build-up of previously unimportant species to economically damaging proportions. There have also been reports of development of resistance to chemical fungicides in plant-pathogenic fungi. In crops where chemical herbicides have been used for a number of years, weed populations are gradually changing; more difficult-to-control weeds are becoming more prevalent as those species that are easily controlled recede.

A variety of alternative pest control or suppression methods have been developed (Council on Environmental Quality, 1972). Integrated pest management endeavors to combine several pest suppression techniques, including the judicious use of chemical pesticides.

OBJECTIVES

This study was undertaken for the purpose of evaluating pest management programs on cotton, peanuts and tobacco in the United States. Specific objectives were as follows:

-- Identify users and locations of major representative pest management programs;

-- For these programs, assess (by years)

(a) biological effectiveness, including economic threshold levels and factors such as crop yield,

(b) types and amounts of costs associated with the establishment and operation of the program,

(c) environmental impact,

Compare the factors set forth above (a, b, c) with comparable farming operations not under pest management;

-- Assess the overall feasibility of pest management for cotton, peanuts and tobacco and specify constraints which may exist for the expansion of these programs;

-- Analyze the extent to which the findings of this study may be applicable to other crops.

Due to the sponsors' information needs and timing requirements, the field phase of this study had to be conducted on a tight time schedule (three months), at a time when many scientists connected with pest management programs are either in the field, on vacation, or busy with the resumption of classes (July through September, 1974).

STUDY APPROACH AND METHODS

To accomplish the objectives set forth above within the time frame stipulated, RvR Consultants engaged as co-investigators four agricultural economists, each of whom had previous experience in dealing with problems of crop protection and pest management. Each of them collected data and information and prepared a report in accordance with the overall project objectives for pest management programs in specific regions as follows:

D. W. Parvin, Jr.	Cotton programs in Louisiana, Mississippi, and Alabama
G. A. Carlson	Cotton programs in North Carolina and Arkansas, tobacco programs in North Carolina
R. D. Lacewell	Cotton programs in Texas, peanut programs in Texas and Oklahoma
R. B. Norgaard	Cotton programs in California and Arizona

This project team met with the project manager, R. von Rümker, at Dallas, Texas on July 10, 1974. This meeting was also attended by the CEQ project officer, W. R. Muir, and by C. D. Reese, EPA project officer. The objectives of the study, the proposed organization of reports, availability and acquisition of data, coordination with other organizations, and many other working details were thoroughly discussed.

The U.S. Department of Agriculture's Cooperative Extension Service (CES) and Animal & Plant Health Inspection Service (APHIS) jointly sponsored and partially funded pilot pest management projects in the United States, beginning in 1971. That year, two pilot projects were established to control insects on tobacco in North Carolina and on cotton in Arizona, respectively. (Both of these projects are included in this evaluation.) Subsequently, this USDA/State program has been expanded rapidly; it included 39 projects in 29 states on 19 major crops in 1973 (Good, 1973).

The USDA Cooperative Extension Service was advised of this study at the time it was initiated by W. R. Muir, Council on Environmental Quality. Additional contacts concerning data acquisition, progress of the study and related matters were maintained by a personal meeting between W. R. Muir, R. C. Scott and others on July 25, 1974, and in subsequent contacts by telephone, by correspondence, and in person between R. von Rümker, R. C. Scott and J. M. Good. USDA/APHIS (J. R. Brazzel) was kept abreast of the study by R. von Rümker.

Several USDA agencies including CES, APHIS, the Economic Research Service and the Agricultural Research Service, as well as the two sponsoring agencies, the Council on Environmental Quality and the U.S. Environmental Protection Agency, provided project members with various reports and documents containing information on cotton, peanut, tobacco, and other pest management programs, and other helpful material. Much additional information was obtained by G. A. Carlson, R. D. Lacewell, R. B. Norgaard, D. W. Parvin, Jr., and R. von Rümker in the field, primarily from personnel directly involved with the cotton, peanut and tobacco pest management programs studied.

As the regional reports reflect, there was considerable variation between states in regard to the quality and quantity of data available on their respective pest management programs. In general, this investigation received outstanding support in most states covered, especially in Texas, Mississippi, Alabama, Louisiana, and Arkansas.

Drafts of the cotton reports by Carlson, Lacewell, Norgaard, and Parvin were received by RvR Consultants in early September of 1974, and drafts of the peanut report by Lacewell and the tobacco report by Carlson were received by mid-October, 1974. RvR Consultants then prepared analyses and overviews of the cotton, peanut, and tobacco programs studied, and summary evaluations. The cotton draft report was submitted to the sponsoring agencies in September of 1974, and the draft report on peanuts and tobacco in October of 1974. Both report drafts were then reviewed in whole or in part by a number of scientists knowledgeable in the subject matter, including Dr. W. R. Muir and Ms. M. Suter of the Council on Environmental Quality, Mr. C. D. Reese and Mr. J. Kempter of the U.S Environmental Protection Agency; Dr. J. M. Good, Dr. J. R. Brazzel, Dr. V. W. Davis and others, U.S. Department of Agriculture; Dr. D. Pimentel, Cornell University; Dr. F. G. Maxwell, Mississippi State University; Dr. R. F. Smith, University of California; Dr. G. A. Carlson, North Carolina State University; Dr. D. W. Parvin, Jr., Mississippi State University, Dr. R. D. Lacewell, Texas A & M University; and Dr. R. B. Norgaard, University of California.

Dr. V. Ulrich, West Virginia University, assisted in the editing of major parts of the report. In addition, each of the regional reports (Appendices A through F) was reviewed by several persons familiar with the individual programs studied, as recognized in each report by the respective authors. Many helpful comments and suggestions were received from these reviewers and utilized in the preparation of this final report.

In the early phases of this study, the terms "pest management" and "integrated pest management (IPM)" were used more or less interchangeably in the project's vocabulary. However, one of the findings of the study was that most of the pest management programs evaluated were not genuinely integrated in the strict sense of the word. Therefore, the term "pest management programs" was subsequently applied, especially in the titles and main body of the report.

The results of this study are presented in this report at three levels of detail and resolution:

(1) Findings and conclusions are highlighted in the sections Summary (p. 7-12)
Conclusions and
Recommendations (p. 12-16)

(2) A comprehensive overview, analysis and evaluation of the regional reports follows next, organized as follows:

Development of Pest)
Management Programs)
Environmental Impact) Combined for
Feasibility) all crops
Constraints on Expansion) studied
Applicability of Findings)
to other Crops) p. 17-46

Trends in Crop Production)
and Pesticide Use)
Users, Locations and)
Characteristics of the) By crops:
Programs Studied) Cotton, p. 47-75
Program Costs) Peanuts, p. 76-92
Program Effectiveness) Tobacco, p. 93-104
Yield)
Pesticide Use)
Production Costs)
Growers' Profits)

(3) The regional reports, Appendices A through F, are the data base of this study; they contain a large

volume of detailed information on the pest management programs studied, assembled by the regional investigators in accordance with the study objectives. Access to the data in the appendices is facilitated by many cross-references throughout the body of the report.

SUMMARY

In this study, 19 cotton pest management programs, 3 peanut pest management programs and 3 tobacco pest management programs were evaluated in regard to the users, locations and characteristics of each program, program costs, program effects on crop yield, pesticide use, production costs and growers' profits. The environmental impact and the biological and economic feasibility of each program were studied, and constraints on the expansion of pest management programs and the applicability of the findings of this study to other crops were assessed. In accordance with the sponsors' timing requirements, most of the data and information presented in this report were collected during the period July through September, 1974. The findings, conclusions and recommendations presented are based largely on the state of affairs as of the fall of 1974.

Key parameters of the programs studied and of their costs and effects are summarized in the following paragraphs. More specific, quantitative data on the 25 pest management programs are summarized in Table 3, p. 52 to 56 for the 19 cotton programs; in Table 7, p. 81 for the 3 peanut programs; and in Table 9, p. 98 for the tobacco programs. Detailed descriptions and evaluations of each program are presented in the regional reports, Appendices A through F.

Program Characteristics

The 19 cotton pest management programs ranged in size from 1,422 acres in one county to 204,000 acres in 23 counties and included programs started between 1949 and 1973. The 3 peanut pest management programs studied comprised 394, 1,315 and 6,558 acres, respectively, and were initiated in 1971 or 1973. For the North Carolina tobacco pest management program, operations were evaluated for the 3-year period 1971 to 1973; the program comprised 8,032 acres in 5 counties in 1971 and expanded to 11,350 acres in 10 counties by 1973.

Program Costs

Operating cost and, to the extent available, implementation cost data were collected for all programs studied. In the cotton pest management programs, annual operating costs reported on a per acre basis ranged from $1.30 to about $5.50/acre (exclusive of costs of insecticides and application). Annual operating costs reported on an "entire program" basis ranged from $20,303 to $911,568. The annual operating costs of the peanut pest management programs evaluated ranged from $7,882 to $40,133 per program, or $1.20 to $53.16/acre. In the North Carolina tobacco pest management programs, annual operating costs ranged from $14.91 to $17.80 per acre.

Program Effectiveness

An overview of the effectiveness of the programs studied in terms of crop yield, insecticide use, production costs and growers' profits is presented in Table 1. In terms of all 25 programs evaluated (19 cotton, 3 peanut and 3 tobacco programs), program effects were as follows.

Crop yield: Adequate yield data were available for 18 programs, and in 13 (72%) of these, pest management program participants experienced increases in yield (quantity and/or quality). There were no changes in yield in 5 programs, and none of the programs studied reported yield decreases.

Insecticide Use: In 18 (86%) of 21 programs for which insecticide use data were available, insecticide inputs decreased, while they increased in 3 programs.

Production Costs: Adequate production cost data were available for 20 programs, and in 17 (85%) of these, production costs of program participants decreased, while there was an increase

Table 1 : Benefits of Pest Management Programs on Cotton, Peanuts and Tobacco

		Cotton	Peanuts	Tobacco	All Crops
# Programs Evaluated		19	3	3	25
Yield	Increased	11	2*	0	13
	Decreased	0	0	0	0
	No Change	2	0	3	5
	No Data	6	1	0	7
Insecticide Use	Increased	3	0	0	3
	Decreased	14	1	3	18
	No Change	0	0	0	0
	No Data	2	2	0	4
Production Costs	Increased	3	0	0	3
	Decreased	13	1	3**	17
	No Change	0	0	0	0
	No Data	3	2	0	5
Profit	Increased	15	2	3**	20
	Decreased	1	0	0	1
	No Change	0	0	0	0
	No Data	3	1	0	4

* Increase in Quantity and/or Quality

** Disregarding Scouting Costs

in production costs due to the pest management program in 3 of the cotton programs.

Profit: Participating growers' profits increased in 20 (95%) of 21 programs with adequate data; there was a slight (6.0%) decrease in 1 cotton pest management program in 1973, the base year for Table 1. This decrease (in the Frio County, Texas program) was due to locally adverse weather conditions which forced a delay of harvest in some fields and required a more intensive boll weevil diapause control program than would normally have been required. The program increased participants' profits in 3 out of 4 years since its inception in 1971.

Environmental Impact

To evaluate the environmental impact of the pest management programs studied turned out to be very difficult. There are no adequate, quantitative base line data available on the effects of "conventional" pesticide use on environmental quality and consequently, there is no basis for comparing the environmental effects of pest management programs to farming operations not under pest management. In many of the USDA/State-supported programs, environmental samples including soil, rodents, forage, fish, water, sediments, toads, and birds were collected and sent to a U.S. Department of Agriculture Laboratory for analysis. However, after storing these samples for several years, the Department decided not to analyze them.

In 18 of 21 programs for which insecticide use data are available, program participants used smaller quantities of chemical insecticides than non-participants, an indirect indication of positive program effects. In a number of programs, the safety and health of field scouts were monitored. No adverse effects or scout health were noted in any of the programs.

Feasibility

All 19 cotton pest management programs studied were found to be biologically and economically feasible, and generally successful in accomplishing their objectives. Among the 3 peanut programs evaluated, only 1 had more than 1 year's operating experience, and this program appeared to be feasible. The biological and economic effectiveness of the remaining 2 programs for which only the start-up year's experiences were available for evaluation remains to be established firmly, but in both cases, prospects appear promising.

On tobacco in North Carolina, management of insect pests only does not appear to be economically feasible or attractive to growers, based on 3-year experiences (1971-1973). In response to these findings, the program objectives were greatly changed and expanded in 1974.

Constraints on Expansion

Several actual and potential constraints on the further expansion of pest management programs or, in positive terms, opportunities for improvement became apparent in the course of this study. These are highlighted briefly in the following section ("Conclusions and recommendations") and discussed in greater detail in the section on "Constraints on expansion" (p. 32 to 42). Regional findings in this regard are included in the regional reports, Appendices A through E (specifically, see pp. B-54 ff., C-39 ff., D-190 ff., F-33 ff.).

Applicability of Findings to Other Crops

The results of this study show that the biological as well as the economic elements of different pest management programs vary considerably between crops, and even between programs for the same crop in different geographical areas. In addition, the biological and economic effectiveness of any given program is subject to year-to-year variations due to changes in weather conditions, pest infestation levels, and other seasonal factors.

On the other hand, certain observations recurred in most of the programs studied and are therefore probably applicable to other crops as well. These are discussed briefly in the section on "Conclusions and recommendations", and in greater detail in the section on "Applicability of findings to other crops"

(p. 43 to 46). Regional findings in this regard are found on pp. C-52 ff., D-196 ff, and E-57 ff.

CONCLUSIONS AND RECOMMENDATIONS

Expansion Potential

There are several potential routes of expansion for pest management, including the following:

- Increase acreage under pest management;
- Increase variety of pest suppression tools and methods;
- Include pests other than insects (and mites);
- Expand pest management into crop management;
- Combine crop and pest management on a multi-crop, area-wide basis.

When the programs studied are compared against these potentials, it appears that while much progress has been made, there is much room for further progress and expansion. For instance, in most of the programs, i.e., in 14 of 19 cotton programs, in 2 of 3 peanut programs, and in all tobacco programs, insect suppression was the main or the only program objective, and the use of chemical insecticides "as needed" (as determined primarily by scouting) was the main pest management tool. Thus, these programs are not really integrated pest management, but "prescription insecticide" programs. Only 5 of the 19 cotton programs, and 1 of the 3 peanut programs had broader crop production improvement objectives. Very few programs included management of pests other than insects and mites (weeds, nematodes, plant diseases, etc.) among their objectives.

> *Recommendation:*
>
> *Promote the expansion of pest management programs and practices towards more comprehensive objectives, and greater diversification and integration of management strategies and tools.*

Research and Education

Lack of basic research does not currently appear to be a constraint on the further expansion of pest management programs on cotton, peanuts, or tobacco. However, much of the available research know-how is available primarily in isolated, compartmentalized form, and is often put together only in the farmer's field. At the farm level, pest and crop management are complex problems, while at public institutions, agricultural research and teaching are traditionally discipline -oriented and -organized. Better and more effective cooperation between all disciplines involved in crop protection and crop production, including economics, is an urgent prerequisite to the further successful development of pest management, plant health, and integrated crop production programs for cotton, peanuts, and tobacco, as well as for other crops. This need is equally apparent in the research area and in the education and training of pest and crop management scientists, administrators, and practitioners.

Recommendation:

Promote more effective cooperation between all disciplines involved in pest management and crop production in research as well as in education and training of pest management and crop production specialists.

Pest Management Delivery Systems

Pest management is a technology that has been and is being developed largely in the public sector, primarily by federal and state research and extension personnel, for implementation in the private sector, i.e., by many individual farmers. Other technologies developed in the public sector are also used mainly in the public sector, such as, for instance, space technology, military technology, etc. The delivery of pest management technology to users thus represents a somewhat unique problem. To the extent that pest management services and chemical pesticides are interchangeable, they compete for the same clients and dollars. Chemical pesticides are vigorously marketed, while pest management is not. Successful implementation and expansion of pest management, especially of comprehensive, genuinely integrated plant health improvement and crop production programs, requires one-on-one contact between technology users and deliverers. In some of the programs studied, this problem was recognized, and an effort was made to strengthen and expand already existing pest management delivery systems; the use of private pest management consultants in the California cotton program is a case in point.

> *Recommendation:*
>
> *The question of the structure and nature (public, private, optimal mix) of pest management delivery systems and related problems at the interface between the publicly developed pest management technology and its private users requires attention. Publicly funded or supported pest management programs should include definitive plans and provisions for delivery of pest management technology and services to users on an ongoing self-sustaining basis.*

Information Needs

In most of the pest management programs studied, program design and execution did not include provision for adequate evaluation of the program's economic and ecological effectiveness. Data on program effects on crop yields, production costs and growers' profits are essential to "selling" pest management to growers. Likewise, adequate information on the benefits (or lack thereof) of these programs to society (tax payers) is needed to justify expenditures of additional public funds for pest management research, development and implementation.

> *Recommendation:*
>
> *Publicly funded or supported pest management programs should include provision (and funds) for evaluation of their economic and ecological effectiveness.*

Federal Support

Among the 19 cotton pest management programs studied in this project, 2 were initiated in 1949 and 1950, respectively, 9 between 1964 and 1971, and 8 in 1972 or later. Federal support for pest management programs from the USDA/State cooperative program first became available in 1971/1972. A comparison of the rates of progress in different programs before and after that time indicates that the infusion of the federal support and funds resulted in expansion and improvement of existing programs and stimulated the establishment of many new programs, including the 3 peanut pest management programs studied and the North Carolina tobacco pest management program. The USDA/State program has also promoted the expansion of pest management objectives and strategies along the lines suggested above under "Expansion Potential" (p. 12).

Likewise, the multi-agency research project entitled "Integrated pest management/the principles, strategies, and tactics of pest population regulation and control in major crop ecosystems", popularly known as the "Huffaker Project", funded jointly by the National Science Foundation, the U.S. Environmental Protection Agency and the U.S. Department of Agriculture, has stimulated a great deal of research and development activity in many areas related to pest management.

For a more comprehensive discussion of the role of government support from a regional standpoint, the reader is referred to pp. D-191 to D-194.

Recommendation:

Continue to provide federal support for pest management research, development, and implementation.

Publicly funded or supported pest management programs at the farm level should include provision for monitoring program effectiveness and biological and economic feasibility, and definitive plans for transfer to self-sustaining status (or discontinuation if not feasible) at the *earliest possible time.*

New programs should be established and funded with a view to further expanding pest management towards its full potentials.

DEVELOPMENT OF PEST MANAGEMENT PROGRAMS IN THE U.S.

The first cotton insect pest control or suppression program meeting the criteria for pest management programs set forth above (p. 1) was initiated in the state of Arkansas in the late 1940's. The development and operation of the Arkansas program are described in detail by Carlson and Grube, p. B-2-3, B-8 ff.

Additional pest management programs were started soon thereafter in other cotton growing states. These included "supervised pest control" programs by private pest management consultants in California (as relayed by Norgaard, p. C-6 ff.); "spray cooperatives" and pest management programs initiated as commercial operations in North Carolina in 1967/1968 (Carlson and Grube, p. B-13 ff. and B-42 ff.); several programs in Texas, primarily involving diapause boll weevil (Anthonomus grandis) control (reported by Lacewell and Casey, p. D-6 ff., D-23 ff., D-45 ff., and D-56 ff.); and a private grower cooperative program aimed at control of the pink bollworm (Pectinophora gossypiella) and the cotton leaf perforator (Bucculatrix thurberiella) in the Safford Valley, Graham County, Arizona (Norgaard, p. C-42 ff.)

All of these programs implemented technology developed over the years in the research programs of the U.S. Department of Agriculture and the land-grant universities and state agricultural experiment stations.

Application of pest management strategies on cotton (and other crops) received substantial additional support and expanded at an accelerated rate following several milestone events in the early 1970's, including the following.

To promote implementation of pest management, the U.S. Department of Agriculture initiated (in 1971) two "pilot pest management projects", i.e., one on cotton in Arizona and one on tobacco in North Carolina, at a funding level of $200,000. The program was expanded in 1972 to 22 projects on 10 crops in 21 states, funded at $1.2 million. In 1973, the program was increased again to 39 projects on 19 crops in 29 states, funded at $2.2 million (Good, 1975).

In 1972, a multi-agency research project entitled "Integrated Pest Management/The Principles, Strategies and Tactics of Pest Population Regulation and Control in Major Crop Ecosystems", popularly known as the "Huffaker Project", was initiated. This bold and imaginative project, managed by C. B. Huffaker and R. F. Smith, University of California, involves 19 universities, several agencies of the U.S. Department of Agriculture, several state agencies, and certain private institutions. The program includes a cotton subproject in which the University of Arkansas, the University of California, Mississippi State University, Texas A & M University, and the U.S. Department of Agriculture cooperate.

The overall project is funded jointly by the National Science Foundation, the U.S. Department of Agriculture, and the U.S. Environmental Protection Agency. From its inception through February 28, 1976, the project received $8,267,900 from the National Science Foundation and the U.S. Environmental Protection Agency, and $1,556,100 from the U.S. Department of Agriculture. An additional $3,112,200 are to be provided by the National Science Foundation and the U.S. Environmental Protection Agency for the last two years of the project, to February 28, 1978. These grants, totalling about $13 million, represent about one-half of the full level of financial effort going into the project. Internal support provided by each of the participating institutions in the form of academic and staff salaries, facilities and (in some instances) a portion of the overhead comprises an amount estimated to be equal to that received from the agencies formally funding the project (Huffaker, 1975).

These two large nationwide programs stimulated a great deal of activity directly or indirectly connected with pest management in federal and state agencies and laboratories, universities, state agricultural experiment stations, extension services, et. Pest management conferences and workshops were held throughout the country, and symposia and paper reading sessions dealing with pest management became a standard component of most or all meetings of scientific societies interested in crops and pests. These activities have produced much new knowledge, and a large number of scientific and popular publications, reviews and unpublished reports dealing primarily with the entomological aspects of pest management. By comparison, relatively little attention seems to have been devoted thus far to problems such as truly interdisciplinary pest and crop management, economics, and how to translate research findings into self-sustaining agronomic practices at the grower level.

The Federal government, through its Legislative as well as its Executive branches, encouraged further research and implementation of pest management. The President's message of February 8, 1972 to the Congress outlining his environmental program includes the following statement on integrated pest management:

> "Chemical pesticides are a familiar example of a technological innovation which has provided important benefits to man but which has also produced unintended and unanticipated harm. New technologies of integrated pest management must be developed so that agricultural and forest productivity can be maintained together with, rather than at the expense of, environmental quality. Integrated pest management means judicious use of selective chemical pesticides in combination with nonchemical agents and methods. It seeks to maximize reliance on such natural pest population controls as predators, sterilization, and pest diseases. The following actions are being taken:
>
> --I have directed the Department of Agriculture, the National Science Foundation, and the Environmental Protection Agency to launch a large-scale integrated pest management research and development program. This program will be conducted by a number of our leading universities.
>
> --I have directed the Department of Agriculture to increase field testing of promising new methods of pest detection and control. Also, other existing Federal pesticide application programs will be examined for the purpose of incorporating new pest management techniques.
>
> --I have directed the Departments of Agriculture and of Health, Education, and Welfare to encourage the development of training and certification programs at appropriate academic institutions in order to provide the large number of crop protection specialists that will be needed as integrated

> pest management becomes more fully utilized.
>
> --I have authorized the Department of Agriculture to expand its crop field scout demonstration program to cover nearly four million acres under agricultural production by the upcoming growing season.
>
> Through this program many unnecessary pesticide applications can be eliminated, since the scouts will be used to determine when pesticide applications are actually needed."

The "Federal Environmental Pesticide Control Act of 1972", an Act to amend the Federal Insecticide, Fungicide and Rodenticide Act (Public Law 92-516, 92nd Congress, H.R.10729, October 21, 1972) mandates the following in Section 20 (a):

> "The Administrator (of the U.S. Environmental Protection Agency) shall undertake research, including research by grant or contract with other Federal agencies, universities, or others as may be necessary to carry out the purposes of this Act, and he shall give priority to research to develop biologically integrated alternatives for pest control".

These Presidential and Congressional mandates were implemented by policy statements, guidelines, and actions of the Executive Branch, especially the Council on Environmental Quality, the U.S. Environmental Protection Agency, and the U.S. Department of Agriculture. As an example, the Secretary of Agriculture's memorandum No. 1799 of February 1, 1973 stated:

> "Non-chemical methods of pest control, biological or cultural, will be used and recommended whenever such methods are economically feasible and effective for control or elimination of pests. When non-chemical methods are not tenable, integrated control systems utilizing both chemical and non-chemical techniques will be used and recommended in the interest of maximum effectiveness and safety".

In November of 1972, the Council on Environmental Quality issued a publication entitled "Integrated Pest Management" in which the need for this approach to crop protection and the current state of the art set forth in a well written and concise form. This publication includes brief outlines of the current state of development of chemical and nonchemical pest management methods.

These Federal initiatives have stimulated and accelerated research activities in the sciences underlying pest management, especially entomology, and efforts to implement pest management technology in field programs. However, research activities and new knowledge will not affect agricultural production, environmental quality, or societal well-being unless and until they are widely accepted and practiced at the grower level. The present study is part of an effort to evaluate the biological and economic feasibility of pest management on selected crops, and the process of transfer of this technology to growers.

ENVIRONMENTAL EFFECTS OF PEST MANAGEMENT PROGRAMS

Of all criteria by which the effectiveness of pest management programs may be measured, their environmental impact is most difficult to evaluate. Very little information is available documenting cause/effect-type relationships between the orderly use (as opposed to accidents, spills, gross misuse, etc.) of specific pesticides on specific crops and environmental quality. Pesticide residues have been found analytically in human tissues, as well as in numerous environmental samples, including soil, air, water, sediment, wildlife, fish, lower aquatic organisms, domestic animals, plants, and other materials collected in various pesticide monitoring programs. However, in most instances, the significance of these residues and their effects (if any) on the organisms or media in which they are present is not clear. In the absence of adequate, quantitative baseline data on the effects of "conventional" pesticide use on environmental quality, it is very difficult to assess the environmental effects of pest management programs as compared to farming operations relying primarily on chemical pesticides for pest control.

Human Health Effects

There are numerous instances, many well documented, in which pesticides, including those used on cotton, tobacco and/or peanuts, have resulted in human illness and deaths. Victims include pesticide applicators, other persons directly working with pesticides, farm workers, as well as persons not directly involved in pesticide operations, especially children. While a detailed study of human health effects was not included in the scope of this study, it should be mentioned that pest management programs will have beneficial effects in this field in several ways, including the following.

(1) The results of this study indicate that adoption of pest management principles and practices will in many instances result in a decrease in the quantities of pesticides used. This in itself should decrease the exposure of pesticide workers, other farm workers, and bystanders to toxic pesticides and thus the incidence of poisoning cases.

(2) Several pest management programs include grower education, encourage more judicious use of pesticides, and promote greater awareness of the hazards associated with pesticide use, including hazards to human health. Better training of persons handling pesticides should help to reduce the pesticide accident rate.

(3) In a number of the programs studied, program participants are transferring the responsibility for insect suppression measures, including insecticide applications, to the pest management organization. (This is the case in the North Carolina "spray cooperatives" and in some of the commercial operations in that state; and in some of the California and Arizona programs.) As more pest management programs develop into area-wide crop protection or crop management schemes, pesticides will increasingly be applied over larger

> areas by professional applicators, instead of by individual growers to their own fields. This will reduce the number of individuals exposed to pesticide concentrates and spray mixtures and should thus be another factor reducing pesticide accidents.

The report by Norgaard (p. C-33 ff.) includes statistics on occupational diseases attributed to pesticides by industry groups and specific pesticides (Table C-11), and by types of pesticides and cotton growing counties in California (Table C-12) for 1971. However, these data do not differentiate between "convential" pesticide use practices and pest management programs and therefore do not provide direct answers to the questions addressed in this chapter. As Norgaard (p. C-36) points out, pest management involves frequent entry of fields by persons employed to check population densities of pests and beneficial organisms. This increases the potential for exposure to pesticide residues and poisonings for this group. However, field checkers are generally informed as to possible harmful effects of pesticides, when fields have been treated, and on the protective procedures that may be required. As a result, no field-checker poisonings have been experienced in California.

The North Carolina tobacco pest management program included a human health effects element (Carlson, 1975). In 1973, blood cholinesterase levels of field personnel in 2 counties were monitored. All determinations fell within normal ranges. (Depression of blood cholinesterase indicates exposure to organophosphate or carbamate insecticides.)

Scout health and safety were also monitored in the Texas pest management programs. Scouts received pre-employment physical examinations, and a medical history was obtained. Blood cholinesterase determinations were run biweekly, and urine samples were analyzed for paranitrophenol levels, indicative of exposure to parathion or methyl parathion. In the Rio Grande Valley program, monitoring data showed that there was organophosphate exposure of the scouts as a group, but there were no clinically significant deviations from normal values in any one individual. No adverse health effects were experienced by scouts involved in any of the other Texas pest management programs either, and it was concluded that there were no significant pesticide-related effects on any scout in the program (Lacewell, 1975).

Environmental Effects

None of the pest management programs reviewed in this study included effective plans or designs for measurement of environmental impact. In some of the USDA/State cooperative programs, environmental samples including soil, rodents, forage, water, sediment, fish, toads, and birds were collected and sent to a USDA laboratory for analysis. However, after storing these samples for several years, the Department decided not to analyze them (Reeves, 1975).

In spite of the dearth of specific data referred to above, it is generally assumed that pesticides have a deleterious effect on the environment outside the target area. In addition, adverse effects of pesticides on the target agro-eco systems in which they have been used have been documented in a number of instances; some of these are reported in the publications cited above in the introduction. Thus, the assumption that decreased use of pesticides will be beneficial to environmental quality is held widely. Based on this assumption, all of the authors of the regional reports (Appendices A through F) used the effect of pest management programs on pesticide inputs as one measure of their environmental impact, rating reductions in the quantities of pesticides used by pest management program participants as a positive indicator of beneficial effects on environmental quality.

Cotton: As the data summarized in Tables 1 and 3 show, 14 of 19 cotton pest management programs resulted in a decrease in the quantity of insecticides used. There was an increase in insecticide use in 3 programs. The remaining 2 programs lack adequate data on insecticide use.

Norgaard's report on the California cotton pest management programs (Appendix C) is the only regional report that includes data on bee, fish and wildlife losses due to pesticides. Fish and wildlife losses attributed to pesticides in the San Joaquin Valley from 1965 to 1969 are summarized in Table 13, page C-37. However, many other crops are produced in the Valley, and it is impossible to attribute all of the reported wildlife losses to the use of insecticides on cotton. Furthermore, there are no quantitative comparisons between pest management program participants' and non-participants' cotton insect control practices for the years in question, nor data on the effects of specific pesticide use practices on wildlife. Thus, while the fish and wildlife loss data are interesting, they make no direct contribution to an assessment of the environmental impact of pest management programs in the area. The same comments in priciple apply to the reports on the adverse effects of pesticides on bees. The bee, fish and wildlife loss data simply document that these undesirable "side-effects" from the use of pesticides did occur, the expectation being that a reduction in the volume of use of toxic insecticides on cotton would most likely reduce such losses.

Peanuts: In general, peanuts receive relatively heavy pesticide inputs in the United States. The per-acre use of insecticides on peanuts increased slightly from 1966 to 1971, but the use of herbicides on peanuts increased by about 50%, and the use of fungicides almost quadrupled.

Adequate pesticide use data are available for only one of the three peanut programs studied. In Frio County, Texas, the adoption of pest management procedures decreased the quantities of insecticides used. The results of field plot trials in Oklahoma (Lacewell and Casey, p. E-46 ff.) suggest that in that area, the use of pesticides on peanuts may be suboptimal, and that increased inputs of pesticides, especially insecticides and/or nematicides, may increase peanut yields and growers' net returns. Thus, it is possible that more intensive peanut pest monitoring, and a better understanding of the combined effects of all production inputs on peanut yields and profits will result in increased pesticide use in that area. If increased pesticide use is equated with adverse effects on environmental quality, negative environmental impacts might be anticipated. However, there is no evidence that the present (or an increased) use of pesticides on peanuts is (or will be) detrimental to environmental quality.

Tobacco: As summarized in Table 9 , p. 98 and documented in detail by Carlson and Cooper (p. F-31 ff.) the North Carolina tobacco pest management program resulted in reduced use of insecticides in each of the 3 years studied. In addition, Carlson and Cooper reported the abundance of several species of beneficial insects, including stiltbugs and Campoletis (p. F-9, Table 2.3), and tiger beetles (p. F-30, Table 3.7). These were sampled in different years inside and outside of the pest management area. There were some numerical differences in the populations of these beneficial insects, but they were statistically insignificant due to large variances.

Data on residues of insecticides in sample areas are included in North Carolina's tobacco pest management program report for 1973. Only traces of currently used chemical pesticides were detected in crops sampled since 1971, indicating that presently used pesticides, at presently practiced use patterns, do not create environmental residue problems, with the exception of methomyl. Residues of this insecticide were found from pesticide useage at a time preceding the pest management program.

> *In summary, no data are available which would permit a rigorous evaluation of the environmental impact of the pest management programs studied in comparison to comparable fields, farms or areas not under pest management. An indirect indication of possible positive program effects is a reduction in the use of chemical pesticides in most of the programs.*

FEASIBILITY OF THE PEST MANAGEMENT PROGRAMS STUDIED

Cotton: The feasibility of each of the cotton pest management programs evaluated in this study was carefully assessed. Details are documented and discussed by Parvin for Louisiana, Mississippi and Alabama in Appendix A, by Carlson and Grube for North Carolina and Arkansas in Appendix B, by Norgaard for California and Arizona in Appendix C, and by Lacewell and Casey for Texas in Appendix D.

Without exception, these investigators report that each program evaluated is feasible. As summarized in Table 1 , p. 9 and, in greater detail, in Table 3, p. 52-56 , cotton yields increased in 11 of 13 programs for which yield data are available, insecticide use decreased in 14 of 17 programs with adequate insecticide use data, cotton production costs decreased in 13 of 16 programs, and growers' profits increased in 15 of 16 programs.

Present and future benefits of pest management programs to cotton producers, to environmental quality, and to society have been well documented for several programs, notably those in Texas. In several instances, it appears that the pest management approach was not only feasible, but was actually a practical, economic necessity. This is the case, for example, in the diapause boll weevil control programs in Texas, and in the programs in the Rio Grande Valley of Texas and in Graham County in Arizona.

Peanuts: The feasibility of the 3 peanut pest management programs studied has been evaluated by Lacewell and Casey (pp. E-16, E-34, E-53). Adequate information and experience are currently available only for the Frio County, Texas program. For this program, there appears to be a cost effectiveness of $8-16 returned per dollar of program cost. In addition to these monetary gains, the program contributed to a downward trend in the quantity of insecticides used. Current producer costs for the program are $1.00/acre. Participating producers have indicated that they would be willing to pay $2.00/acre or more to continue the program.

These factors indicate that the program is attractive to growers, and that it is effective in accomplishing its principal objective, management of the burrowing bug (Pangaeus bilineatus). The program appears to be feasible both biologically and economically.

The remaining 2 programs, both supported by USDA grant funds (Comanche County, Texas and Oklahoma), were implemented only in 1973. Both programs experienced various start-up difficulties, including late availability of funds, inadequate time and funds for program planning and preparation, and late start of field operations relative to the vegetation period of peanuts. In both programs, actual costs per program acres were excessive. As of the fall of 1974, data and operating experiences available were insufficient for a realistic assessment of the economic feasibility of these programs.

Both of these programs address not only insect problems, but include consideration of plant diseases, nematodes, weeds, soil fertility, and plant health. It is not clear how much such an integrated pest management/plant health service would be worth to peanut growers, but some indications in this regard may be gleaned from the Oklahoma program. This program has several interesting features. It provides not only pest management advice to participating growers, but includes field demonstration tests in which different peanut management practices and production inputs are evaluated comparatively. Novel monitoring techniques such as infrared photography and remote sensing are being evaluated. A mobile diagnostic laboratory of the type successfully used in Virginia for many years is employed in the program. Thus, it appears that this program involves an interdisciplinary effort to develop a complete, efficient peanut production system, focusing on plant health improvement, rather than only on the management of one or a few specific pests.

Plans for 1974 for the Oklahoma program included making suggestions to participating growers based on populations of harmful (and beneficial) insects, weeds, nematodes, and diseases, to be monitored by plant health teams weekly from June through August, and bi-weekly in September and October. Growers will also receive advice on soil fertility and irrigation. Each grower will receive a "field report" following each visit by the plant health team. The field report will be supplemented by the services of the mobile plant health diagnostic laboratory which is staffed with a technician and a field plant health supervisor. Participating growers are paying a fee of $8/acre for this service for the first 50 acres, $7/acre for the next 25 acres, and $6/acre for the balance of acres in the program. Plans for 1975 envisioned expansion of this approach to additional crops.

The biological and economic effectiveness of this comprehensive, innovative approach that incorporates interdisciplinary inputs and several different techniques (field monitoring, field test plots, mobile diagnostic laboratory, with remote sensing perhaps to be added) remains to be established. However, the large differences in peanut yields and in gross and net returns obtained in the 1973 Hughes County field demonstration plots indicate that there is considerable room for improvement of peanut production in Oklahoma. The potential net profit improvements indicated are of the order of $160-240/acre. Potential profit increases of this magnitude could well support the cost of an effective, comprehensive plant health improvement service.

Peanut programs based on integrated management of pest complexes as well as production practices have been operated successfully for many years in Eastern peanut growing areas including Virginia and Georgia. These programs were initiated long before the term "integrated pest management" became popular. In Georgia, for instance, this approach quadrupled peanut yields in 20 years (Good, 1974a). Due to limitations in available time and funds, it was not possible to include an evaluation of these older programs in the present study.

Tobacco: The gross return of tobacco in North Carolina is about $2,000/acre. The North Carolina tobacco pest management program, by its published objectives and activities from 1971-1973, was not an integrated pest, but an insect management program. Program objectives did not include management of tobacco diseases, nematodes, or weeds, nor soil fertility or general plant health considerations. According to the information analyzed by Carlson and Cooper (p. F-27 to F-29), the estimated costs for insecticides and application on all North Carolina tobacco farms in 1971 was $11.28/acre. Pest management program participants may have realized cost savings from reduced use of insecticides ranging from $2.51 to $5.55/acre, averaging $4.26/acre for the 3 year period 1971-1973. The latter figure amounts to 0.2% of the farm value of one acre of tobacco, while the total average cost for insect control for all North Carolina tobacco growers, $11.28/acre, amounts to 0.56% of the farm value of the crop per acre. Thus, tobacco insect control is not a major tobacco production cost item.

As summarized in Table 9 , p. 98 , the total cost of insect management (including scouting, extension service and professional support, overhead, and cost of insecticides and application) for program participants ranged from $23.53/acre in 1972 to $23.68 per acre in 1971 and 1973. The cost of insect management per acre of tobacco in the program was more than twice as high as the estimated cost of insecticides plus application on all North Carolina farms. The per-acre costs of scouting (scout salaries and travel) alone, disregarding all other program expense elements, were higher than the savings in insecticides and application costs. (Program participants realized a small actual increase in profits only because they did not make any contributions to the costs of the program.)

For these reasons, it does not appear that a pest management program limited to the management of insect pests on tobacco is economically feasible in North Carolina.

As Carlson and Cooper point out in the concluding remarks of their detailed study (p. F-35), yield and quality improvements were not part of the North Carolina tobacco pest management program up to 1973. Due to the high value of the tobacco crop, small improvements in yield quantity or quality will justify considerable expenditures of management resources. Thus, while tobacco insect management may not be economically feasible by itself, it may well be viable as one component in an interdisciplinary tobacco pest management/plant health improvement program. This was recognized by USDA and North Carolina program managers and consequently, the program was restructured, and a new 3-year program began in crop year 1974. The new thrust will provide for integrated management of pest problems caused by insects, weeds, diseases, and nematodes, and for sucker control. It is known that the principal losses of tobacco are caused by diseases and nematodes, and individualized recommendations for management of these pests will more likely be economically attractive to tobacco growers. For example, a large percentage of the tobacco acreage is treated with expensive soil fumigants for the control of soil-borne disease organisms and nematodes. These treatments cost $20 to $60 per acre; and substantial savings to growers could probably be realized by more precise application based on needs and use of less expensive chemicals, depending on the pests present (Good, 1974a).

> *In summary, all cotton pest management programs studied in this project were found to be feasible and generally successful in accomplishing their objectives, with differences in objectives between projects and areas.*
>
> *Of the 3 peanut programs studied, only one (Frio County, Texas) had more than one year's operating experience. This program appears to be feasible. Both of the Oklahoma programs were initiated only in 1973 and therefore had only one year's operating experience at the time when the field phase of the present study was conducted (early fall of 1974). The biological and economic effectiveness of these programs*

remains to be established firmly, but prospects appear very promising.

On tobacco in North Carolina, management of insect pests only does not appear to be economically feasible or attractive to growers, and in response to these findings, program objectives were greatly changed and expanded in 1974.

CONSTRAINTS ON EXPANSION OF PEST MANAGEMENT PROGRAMS

Review of the pest management programs studied in this project, including the regional investigators' projections, indicates that these programs could expand in several different ways, i.e.:

- -- cover more acres;
- -- use greater variety of insect suppression tools and techniques;
- -- include pests other than insects (and mites);
- -- include crop (not just pest) management;
- -- include crop and pest management on a multi-crop, area-wide basis.

Evaluating the pest management programs studied, especially those on cotton, against these potentials, it appears that most of them are, at this stage, still primarily "prescription insecticide" schemes. Some cotton programs have expanded prescription insecticide use almost to an area-wide basis. The use of insect suppression tools other than insecticides is minimal compared to the use of insecticides. On cotton, there does not appear to be any expansion toward the management of pests other than insects (and mites). Some cotton programs are developing into crop/insect management schemes.

This analysis should not detract from the success and viability of the pest management approach on cotton; it simply indicates that there is much room for expansion, and that the development thus far has largely been in the area where the immediate needs were the greatest. The USDS/State-supported programs have been instrumental in stimulating the expansion of pest management. In particular, the USDA/State program has brought substantial additional cotton acreage under pest management. It has reinvigorated some of the older programs that were showing signs of sagging, and has given much added impetus to the adoption of the crop development/plant measurement approach and thus to the expansion of pest management in the direction of total crop management. The "Huffaker program" has added substantially to the research base for these efforts in the fields on which it focuses, i.e., the principles, strategies and tactics of the population regulation and control of pests, primarily foliar insects, on cotton and several other crops (alfalfa, citrus, pines, pome and stone fruits, and soybeans). Both of these programs (USDA/State and "Huffaker"), of course, benefit from, and build further on the vast base of research and technology developed over many years by the U.S. Department of Agriculture, public and private universities, State Agricultural Experiment Stations and Extension Services, private industry, and others.

The data presented in this study and in other reports show that pest management programs have produced many benefits to agriculture as well as to society at large. However, in view of the magnitude of the effort, the amounts of public funds (both Federal and State) that have been invested, and the favorable results at hand, the question arises: If pest management is so advantageous to all, why is it not adopted more rapidly?

Integrated pest management is a new technology that might be compared to the development of a new product or technology in an industrial setting in terms of the phases involved in such a process, including research, development, pilot marketing, and full commercial production, marketing and use.

In the research phase, candidate new products (or technologies) are invented and tested, and their suitability for their intended purpose is determined. A crucial step in the development phase of a new product, after its basic effectiveness has been established, is the determination of its economic feasibility, including obtaining answers to questions such as:

-- How much does it cost?
-- What will it do for users?
-- How much is it worth to users?
-- How much will users pay?
-- How does it compare to present products or practices?

In the commercial world, it would not be possible to successfully introduce and market a new product without solid answers to these questions.

Even after a product proceeds from research and development to commercial production, marketing and use, there is an ongoing need for research support. Continued research is required for product improvement, and to adapt the product or technology to changing user needs. Development or technical service personnel assist users in obtaining optimal benefits from the product, handle problems of unsatisfactory performance and/or other user complaints, provide communication between research and users, and promote new and expanded uses. Very often, a new product is first manufactured and marketed on a limited, or pilot scale to verify or correct the economic, functional and operational forecasts made earlier.

Finally, full commercial production, marketing and use present the acid test on the validity of all previous forecasts and expectations. The well-known case of Ford's Edsel, among others, documents that massive product failures are still possible at this late stage.

Comparing pest management as a new technology to the development of a new product or technology in a commercial environment provides a frame of reference helpful to the identification of certain strengths and weaknesses.

Research

Considerable research has been conducted in the past on the pests including insects, nematodes, diseases, weeds, etc., of cotton, peanuts, tobacco, and many other crops, as well as on many other facets of the production of these crops. However, up to the present, such research appears to have been conducted largely on a disciplinary basis, without effective interdisciplinary cooperation, leaving it up to the grower to put it all together, and to work out as best he (or she) can unforeseen interactions between the different pieces of technology that were developed in isolation.

Cotton: As pointed out above, a broad base of research know-how on cotton insects and other pests has been developed in the United States over many years. Among the commodities studied in this project, cotton is the only one included in the "Huffaker Project". By its very title and its stated objectives, this program is a research and method development effort. It strives to be multi-disciplinary, but seems to be heavily tilted toward entomology. Furthermore, while inputs from economists were planned, it seems that in actual fact, economists have had only limited influence on, and participation in program planning, design, and execution. This deficiency may become serious in areas where Huffaker project activities progress from research into the development and implementation phases of pest management.

Peanuts: The peanut pest management programs studied utilize and implement research results developed in the states concerned and elsewhere and rely on ongoing research support and backup. The Oklahoma program shows that field observations often raise questions that can be resolved successfully only by continued research participation and support. Lacewell and Casey emphasize that both of the Texas peanut pest management programs also rely heavily on, and receive, strong research backup.

Thus, lack of research data does not appear to be a major constraint on expansion of peanut pest management programs, but ongoing research support is clearly an important requirement.

Tobacco: Rabb et al. (1974) have pointed out and documented that a substantial pool of research knowledge exists in regard to tobacco production and, in particular, in regard to the insects and diseases affecting tobacco. These authors make the following observation regarding utilization of this research know-how:

> "The integration of pest control actions into the tobacco production system has been a slow step-by-step process taking many years. Most of the inputs by pathologists and entomologists have been made separately, and each group has developed and implemented its own 'action' program."

Rabb et al. (1974) cite several examples of tobacco production improvements made unilaterally by one discipline, without cooperation with other disciplines in the research (or development) phase. For instance, it was found that the introduction of nematode-resistant tobacco varieties aggravated damage by the tobacco hornworm, Manduca sexta. Other examples include the role of insects in the transmission of tobacco diseases; the increased susceptibility of plants to disease because of insect damage; and the influence of the use of maleic hydrazide, a chemical employed most frequently for chemical sucker control on tobacco, in reducing overwintering populations of the tobacco hornworm.

It appears that sufficient basic knowledge on tobacco pests exists to support pest management programs on tobacco. However, more effective cooperation between all scientific disciplines involved in tobacco pest management and production would seem to be required in the further development of integrated pest and crop management systems for tobacco.

Development

The USDA/State-supported "pilot program for integrated pest management", by its title and objectives, would correspond to the development and pilot marketing phase in the life of a new commercial product. This comparison suggests several opportunities for improvement.

Economic and ecological evaluation: As pointed out above, studies on economic effectiveness and feasibility are an essential step in the development phase of a new product or technology. In this regard, most of the pest management programs evaluated in this study leave much to be desired. It appears that in most or all of these programs, economists were not involved in program planning and design and, to the extent that they participated at all, had mostly inadequate data to evaluate ex post facto.

Scott (1974) and other leaders of the USDA/State cooperative pest management program have emphasized that "Extension pest management programs are designed to teach farmers to adopt integrated biological, cultural, and chemical technology to control agricultural pests", and that "these programs have both economic and environmental objectives -- to help maximize incomes of producers and reduce potential adverse environmental effects of pesticides".

In the light of these program objectives, it is surprising that the design and funding of the programs apparently did not provide for thorough, systematic evaluation of their economic and environmental effects. Economic benefits to be obtained from pest management programs will be far more persuasive to growers than other factors. If pilot pest management programs are intended to promote grower acceptance and implementation of integrated pest management, generation of adequate economic data would appear to be essential. If, in addition, these programs have environmental objectives, then they should also include provision for monitoring achievement of these objectives.

Information feedback: The information feedback loop in the USDA/State program appears to be rather long, slow, and inefficient. For instance, data necessary for an evaluation of the effectiveness of the 1972 program were not collected from State project leaders until late in 1973, and were not summarized and published until the latter part of the summer of 1974. An evaluation of the 1973 programs was not available in the fall of 1974. Results of analyses of the environmental samples collected in 1972, were not available in the fall of 1974, and in the spring of 1975, it was announced that plans to analyze these samples had been abandoned. Some pest management workers contacted in this study in the early fall of 1974 were reluctant, unwilling or unable to provide information because they had not collected or analyzed their 1972 and/or 1973 data as yet.

In the commercial world, beginning a new year's cycle in the development of a seasonal product (such as pest management) without prior complete assessment and exploitation of the preceding year's experience would be considered inexcusable. By comparison, the present information handling practices in many of the programs studied in this project cause long delays in the application of field experience. More rapid and efficient collection and evaluation of field data and more rapid communication of the findings to all program participants and to other interested agencies and persons would appear to be highly desirable.

Pest Management Delivery Systems

Delivery of pest management technology to growers may be compared to the marketing of a new product. In the commercial environment, it would be very difficult, if not impossible for any new product, no matter how good, to gain wide acceptance and use without effective marketing. In the United States as well as in many other "free market" countries, marketing has traditionally been a function of private enterprise.

Chemical pesticides and pest management services, to the extent that they are interchangeable, compete for the same users and dollars. In the U.S., chemical pesticides are promoted and marketed vigorously. By comparison, pest management does not appear to be "sold" nationwide or regionally with any degree of vigor. It thus appears to be in the position of a new product without effective marketing.

Cotton: In the cotton pest management programs studied in this project, pest management is being delivered to growers through private pest management consultants or organizations in some cases (North Carolina, Arizona/Graham County, and California's private consultants), through the publicly funded Extension Service in others. The two systems are not mutually exclusive; most or all private consultants rely in varying degrees on the research, back-up, and support of Federal and State research and extension personnel. In some states, notably in California, the administrators of the USDA/State-supported cotton pest management program have endeavored to expand private pest management consulting. In other states, private pest management activities do not appear to be encouraged by the State program.

Peanuts: No private enterprise "marketing" or delivery of the pest management technology to users appears to be involved in any of the peanut pest management programs studied. In the case of the grower-initiated Frio County, Texas program, pest management is delivered to growers by State agricultural agencies. Research support is provided by the Texas Agricultural Experiment Station, and pest management monitoring and advisory services are delivered directly to peanut producers by or through the Texas Agricultural Extension Service. Program users pay for the costs of scouting, and the services of the State agencies are paid from State funds.

The other two programs studied did not appear to encourage private enterprise participation either. If the Oklahoma program accomplishes the ambitious objectives envisioned for 1974, 1975 and beyond without private enterprise participation, a considerable expansion of the role of State agencies, especially of the Extension Service, would seem to be required.

Tobacco: No elements of private enterprise delivery of pest management technology to growers appear to be involved in the North Carolina tobacco pest management program. Program participants receive the "product", pest management services and advice, directly or indirectly from State agencies, primarily the Extension Service.

Successful implementation of integrated pest management, especially of more comprehensive plant health improvement programs, requires one-on-one contact between pest management users and pest management deliverers. This requirement appears to be at odds with several basic principles that apply to all extension programs, but especially to developing pest management programs, as stated by Good (1974b) as follows:

- Extension must not compete with the private sector.
- Extension cannot provide specialized services to select individual or groups.
- Extension must present alternative choices so that growers have sufficient knowledge to make enlightened decisions.

A study of the relative advantages and disadvantages of the delivery of pest management technology with or without private enterprise participation was not included in the scope of this study. However, the facts discussed above indicate that a better understanding of the optimal mix between public and private activity in the delivery of integrated pest management technology to users may be important to the further planning and implementation of public policies in this field.

Interdisciplinary Research, Education and Training of Personnel

Pest (not just insect) management and plant health improvement are complex problems that clearly require an interdisciplinary approach. Tackling crop production problems in an interdisciplinary manner is not the traditional approach within the U.S. Department of Agriculture, nor at U.S. universities and State Experiment Stations. Agriculture-oriented universities in the U.S. are traditionally discipline -oriented and -organized in research and education, and this seems to carry through to the Extension system. Effective cooperation between entomologists, plant pathologists, nematologists, weed scientists, plant physiologists, plant breeders, agronomists, engineers, chemists, and other disciplines involved in crop production appears to be feeble or nonexistent in most academic institutions. Cooperation between the biological and physical disciplines and economists and sociologists likewise is vastly underdeveloped.

It appears that more effective cooperation between all disciplines involved in crop production is an urgent prerequisite to the further successful development of integrated pest management or plant health programs for cotton, peanuts and tobacco, as well as for other crops. Such interdisciplinary cooperation is essential for the efficient solution of research problems, as well as for the education and training of field personnel and growers.

Program Management

At this writing (1974/1975), overall responsibility for progress of the various federally supported pest management programs, and for optimal use of public funds appropriated for this purpose appears to be ill defined, and diffused throughout different Federal and State agencies. The question arises whether the interest of farmers as well as of society (and taxpayers) at large would not be better served by tighter management, i.e., if one agency would be given specific overall responsibility and authority for the further development and implementation of pest management programs.

This function would be comparable to that of a product manager in industrial settings. The product (or program) manager concept has been used extensively and successfully in other mission-oriented governmental activities such as, for instance, the space program and the military services. Management tools such as the "Program Evaluation and Review Technique" (PERT), critical path method, and/or others are often used with much success; they facilitate program coherence, communications, and timely completion of individual work elements.

None of these management methods appear to be in use in the USDA/State program, or between that program and the "Huffaker Project" and other pest management efforts. Very tight management of the entire program may not be feasible or even desirable. However, there does appear to be a need for more effective guidance and support of individual program elements, including promotion of more effective coordination and cooperation between all elements necessary to the efficient further development of truly integrated, practical pest/crop management systems; improvement of information collection and handling procedures, and strengthening of a communications system through which information can and will flow swiftly in both directions, i.e., from research workers through extension and other advisory personnel to growers, and vice versa. Another function of such overall pest management program guidance would be to avoid unnecessary duplication of effort, to pinpoint and correct weaknesses, and to keep the overall program moving in the right direction.

In summary, much has been accomplished in the establishment and expansion of pest management programs on cotton, peanuts and tobacco, especially in the last 3 years (since 1972) through the USDA/State-supported program, but a great deal more remains to be done to develop this technology towards its full potential, and to make it permanently viable and self-sustaining. There are opportunities for improvement in the following areas, especially in publicly funded or supported programs:

-- *Evaluation of the economic and ecological effests of pest management programs;*
-- *Information feedback;*
-- *Pest management delivery systems;*
-- *Interdisciplinary research, education and training of personnel;*
-- *Overall program guidance.*

Note: As emphasized above in the introductory sections of this report, the findings and conclusions presented are based on data and information collected in the field in the early fall of 1974.

APPLICABILITY OF FINDINGS TO OTHER CROPS

In this study, 19 pest management programs located in 8 major cotton-producing states, 3 peanut pest management programs located in the states of Texas and Oklahoma, and the North Carolina tobacco pest management program were described and evaluated in detail. In all evaluations, prime emphasis was placed on the practical, economic effectiveness and feasibility of the programs studied. Most previous reports on pest management programs have dealt primarily with their research and biological (largely entomological) aspects, instead of their economic effectiveness and practicality at the grower level. To the best of our knowledge, comparable, economically oriented, down-to-earth evaluations of pest management programs on other crops do not currently exist.

The present study has shown that there are considerable differences between pest management programs on the same crop in different states, and even within states. For instance, each of the 3 peanut programs evaluated had different objectives, even though all were located in two neighboring states, in the same general area of the U.S. Similar variations in origin, experience to date, and objectives were observed among the cotton programs studied.

Furthermore, it is interesting to note that Oklahoma peanut producers, growing a crop worth $375/acre (1973 U.S. average), were reported willing to pay $8/acre for an integrated pest management/plant health improvement service. California cotton producers, growing a crop worth about $250/acre (1973 California average), pay private consultants $2 to $6/acre for pest management and general production advice, depending on the level of service (Falcon, 1974). On the other hand, North Carolina tobacco producers, growing a crop worth $2,000/acre, have contributed nothing to the cost of their USDA/State-supported insect management program between 1971 and 1973.

Thus, it appears that the biological as well as the economic elements of pest management programs vary greatly between different crops and geographic areas. This is not surprising in view of the great variations in the farm values of different crops, the importance of insects, diseases, weeds, and other pests in relation to other production problems, the availability of basic prerequisites for successful integrated pest management, and many other pertinent factors. These numerous variables explain why in many ways, each pest management program has at least some unique characteristics, and braod generalizations are of questionable value.

On the other hand, certain observations recurred in most or all of the pest management programs studied in this project and are therefore probably applicable to other crops as well. These include the following.

1. The biological and economic effectiveness of any given program is subject to year-to-year variations due to changes in weather conditions, pest infestation levels, and other seasonal factors. Therefore, evaluation of individual programs over time is likely to be more informative and meaningful than studying different programs or averages for single years in a "time slice" fashion. The latter approach would obscure differences between programs and lead to erroneous conclusions if the year evaluated was unusual, which most years are in one way or another.
2. Most of the cotton, peanut, and tobacco pest management programs evaluated lacked adequate provision for evaluation of their economic and environmental effects in their planning, funding and execution.
3. One of the major constraints on the further expansion of integrated pest management programs appears to be the lack of effective interdisciplinary research, planning, and field implementation of research know-how.

4. There is a shortage of versatile, interdisiplinarily educated and trained crop management scientists, administrators and practitioners.
5. The problem of optimal delivery systems of integrated pest management technologies to growers needs attention. In the majority of the pest management programs studied, the Cooperative Extension Service currently appears to be the primary delivery system. There is a question if in the long run, this role will be compatible with the overall mission of the Extension Service which considers itself primarily an educational agency that should not provide specialized service to individuals. On the other hand, effective pest management delivery and implementation will have to include furnishing specific, individualized advice to growers.
6. As pointed out in greater detail in the section on constraints, integrated pest management at its current state of development shows many of the symptoms of a new commercial product that lacks effective development and marketing management. Several of the programs evaluated appear to be stalled, or headed for trouble at the crucial threshold between research/development and full commercial viability and implementation, without clear plans how and by whom they could or should be lifted across.
7. The foregoing, seemingly critical statements should not take away from the fact that in most of the programs studied in this project, much progress has been made in a relatively short period of time. The USDA/State cooperative program has successfully acted as catalyst; it has mobilized many resources and greatly accelerated the development and expansion of integrated pest

management in the field. The very fact that certain problems of commercial implementation and use of pest management on a large scale at the grower level are now at hand is a result of the success of the program thus far.

COTTON PEST MANAGEMENT PROGRAMS

BACKGROUND

Many studies on the biology, population dynamics and control of cotton insects have been conducted. At the present time, more pest management programs are in operation on cotton than on any other crop in the United States. This is due primarily to two facts, i.e., (1) several of the serious failures of chemical insecticides have involved cotton insects, and (2) almost 50% of the total quantity of insecticides used by farmers in the U.S. in recent years was used on cotton (U.S. Department of Agriculture, 1968b, 1970, 1974b).

Further details on development of pest management programs, especially programs on cotton, have been presented above in the section entitled "Development of Pest Management Programs in the U.S." and are therefore not reiterated here.

A variety of different insect pests occur on cotton in the United States. Their relative economic importance varies in different parts of the country. Cotton pests of the Southern cotton growing areas and their interactions with the cotton plant, with beneficial parasites and predators, and with other elements of the environment are discussed by Parvin (see p. A-2 to A-16). In the Far West, principal pests on cotton include mites, lygus bugs, the cotton bollworm, *Heliothis zea*, the pink bollworm, *Pectinophora gossypiella* (in Southern California and Arizona), and the cotton leaf perferator, *Bucculatrix thurberiella*. These regional differences in the relative abundance and importance of injurious as well as beneficial insects and mites on cotton necessitate different pest management strategies, as discussed in greater detail in Appendices A, B, C, and D.

TRENDS IN COTTON PRODUCTION AND PESTICIDE USE

The U.S. Department of Agriculture has collected data on the quantities of pesticides used by U.S. farmers in 1964, 1966, and 1971. These data are presented in Table 2 , along with the

Table 2: U.S. Cotton Acreage, Insecticide Use on Cotton, and Production of Insecticides, 1964 - 1973

Year	1964	1966	1971	1973
Cotton Acreage (1,000 Acres)	14,836	10,349	12,355	12,501
Insecticide Use on Cotton				
- Total (1,000 lbs. AI)	78,022	65,368	73,357	75,006[1/]
- per Acre (lbs. AI)	5.25	6.31	5.93	6.0 [1/]
Insecticides Produced in U.S. (1,000 lbs. AI)	463,321	561,814	564,818	639,169
Cotton Insecticide Use Relative to U. S. Production	16.8%	11.6%	13.0%	11.7%[1/]

Sources: U. S. Dept. of Agriculture (1966, 1968a, 1968b, 1970, 1973c, 1974a, 1974b)

U. S. Tariff Commission (1974)

1/ Estimates

total U.S. cotton acreage, and the total U.S. production of insecticides in the years in question, plus 1973. The U.S. cotton acreage varied from a high of 14.8 million acres in 1964 to a low of 10.3 million acres in 1966; it was close to 12.5 million acres in 1971 and 1973. The USDA insecticide use data indicate that in 1964, an average of 5.25 lbs. of insecticide active ingredients were used on cotton, 6.31 lbs./acre in 1966 and 5.93 lbs./acre in 1971. The quantity of insecticides used on cotton was 16.8% of the total quantity of insecticides produced in the U.S. in 1964, 11.6% in 1966, and 13.0% in 1971.

Assuming that cotton growers used an average of 6.0 lbs. of insecticide active ingredient per acre on cotton in 1973, total insecticide consumption on cotton for that year would have been about 75 million lbs. of active ingredients. This estimate would place the quantity of insecticides used on cotton as percent of the total U.S. production of insecticides at the low end of the scale of the actual experience in 1964, 1966, and 1971 and thus appears plausible.

The data presented in Table 2 do not indicate any trend in the use of insecticides on cotton. All but one of the USDA/State-sponsored cotton pest management programs were initiated only in 1972 and probably did not achieve full effectiveness until 1973 or 1974. It will be interesting to see if these programs will result in a statistically noticeable decrease in the use of insecticides on cotton in the future. The U.S. Department of Agriculture's Economic Research Service is planning a survey of pesticide and fertilizer use practices for crop year 1976. Additional data on pesticide use will be collected as part of the Agency's surveys of costs of production by commodities (Davis, 1974).

USERS, LOCATIONS AND CHARACTERISTICS OF THE PROGRAMS STUDIED

In this project, 19 individual cotton pest management programs were studied. The locations of these programs, superimposed on a dot-map of the U.S. cotton acreage harvested in 1969, the latest year for which such dot-maps are available, is given in Figure 1 . This map shows that the present study covered most of the major cotton producing areas in the United States.

An overview of the characteristics of the cotton pest management programs evaluated, including their locations, purpose, and starting years are presented in Table 3 . The entries opposite "Ref(erence) Page" refer to the page numbers in the regional reports where these programs are described and assessed in detail. The data in Table 3 pertain to the year 1973, except for a few instances (marked appropriately) where 1973 data were not available. 1973 was chosen as the base year for this overview because it is the most recent year for which data are available at this writing (July - August, 1974). Secondly, many of the USDA/State-supported pest management programs were initiated rather hastily in 1972 and did not have a full year of "normal" operation until 1973.

The cotton pest management programs studied vary considerably in regard to users, purpose, starting year, and acreage covered. The major features of these programs are as follows (programs discussed in approximate decreasing order of acres covered).

Arkansas: The program with the longest history is that in Arkansas, started in 1949 for the purpose of improving cotton insect control in the state. It has been carried out primarily by scouts trained and supervised by the Extension Service. Detailed data on the Arkansas program, by years from its inception to the present, have been collected and evaluated by Carlson and Grube (p. B-8ff). Their report includes number of scouts and scout supervisors; number of counties, cotton acres, cotton fields and farms in the program; scout load characteristics and costs; and grower pest management training activities. In 1973, the Arkansas pest management program was one of the three largest programs studied; it included 204,000 acres on 892 farms in 23 counties and employed 149 scouts. The program operates in practically all cotton-growing counties of Arkansas and covers

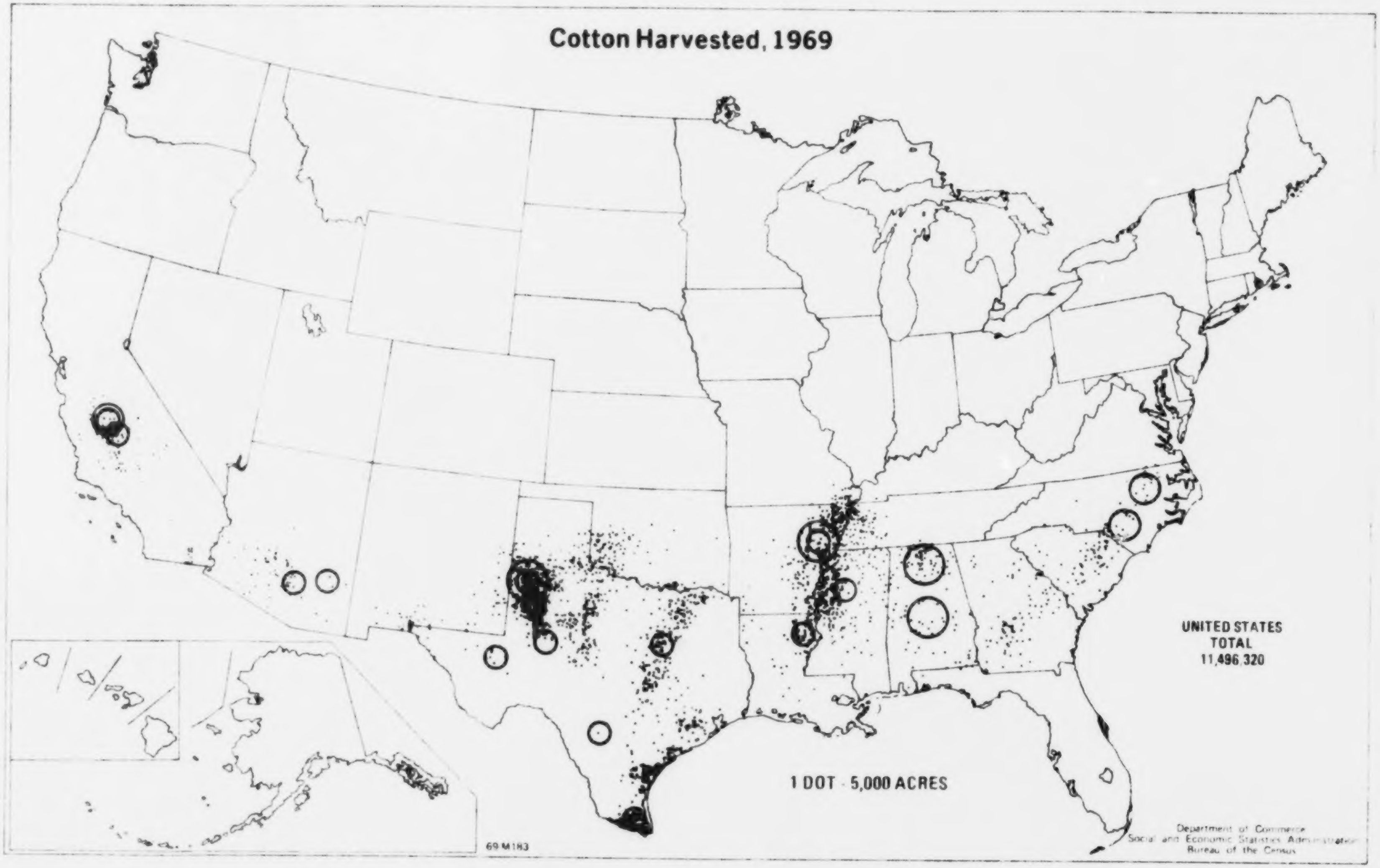
Cotton Harvested, 1969
UNITED STATES
TOTAL
11,496,320
1 DOT - 5,000 ACRES
69 M183
Department of Commerce
Social and Economic Statistics Administration
Bureau of the Census

Figure 1: Locations[1/] of the Cotton Pest Management Programs Evaluated in this Report Relative to the Geographic Distribution of Cotton Production in the U.S.

1/ Program locations identified by circles.

Table 3 : Characteristics, Costs and Benefits of 19 Cotton Pest Management Programs, 1973[1]

Program	Arkansas PM Program	North Carolina Cooperatives	North Carolina Commercial Operations	Mississippi PM Program	Alabama PM Program
Location	Eastern half of State	Several Counties		Grenada-Yalobusha co.'s	North,West& Central Ala.
Purpose	Insect pest suppression	Group purch. of insect control	Insect pest suppression	Insect pest (boll weevil) suppression	Insect pest suppression
Ref. Page	B-8, B-35 ff	B-13 ff., B-42 ff.		A-31 ff.	A-41 ff.
Year Started	1949	1967	1968	1972	1972
Area	23 Counties	Several Counties		2 Counties	17 Counties
Acres) in	204,000	33,516	11,700	13,827	115,000
Farms) PM	892	401	58	97	599
Fields)	5,726				3,280
# Scouts	149	37	10	13	73
# Scout Supv.	6				9
Acres/Scout	1,417	1,027	1,625	1,063	1,575
Pest Mgmt. Acreage Ratio	18% of State cotton acr.	18.4% of State cotton acreage	6.4%	73% of cotton acr. in area	40% of cotton acr. in area
Insect Management Costs, $	per Acre	per Acre		per Acre	per Acre
Scouts	1.04	1.18		1.25	1.25
Scout Travel	0.01				
Scout Supv.	0.08*				
Co. Agents	0.28*	1.80			
Prof. Support	0.09*	1.61*			
Other	0.07*				
Subtotal	1.57	4.59			
Insecticides	5.40	15.50		13.34	18.79
Application	3.60	11.74		8.30	
Total	10.57	31.82		21.64	
Growers' Funds	10.05	30.22		1.25	1.25
Public Funds*	.52*	1.61*			
Benefits:					
Cotton Yield	+ 8%	+ 230 lb[8]		No data	Above state avg.
Insectic. Use	- 20%	+ 24%		- 2.3 appl.'s	- 2 to 4 appl.'s
Product. Cost	- 1%[7]	+ $10		- $5.20[9]	- $6.78
Profit	+ 9%	+ $84		Increased	Increased

Notes on page 56

Table 3 : Characteristics, Costs and Benefits of 19
Cotton Pest Management Programs, 1973[1/]

Program	Louisiana 1972	California		Arizona	
Location	Catahoula, Grant & Tensas P[illegible]	Pest Mgmt. Consultants San Joaquin Valley	Scout Program San Joaquin Valley	Graham Co. Safford Valley	Pinal Co.
Purpose	Insect p[illegible] suppress[illegible]	Suppr.Lygus & bollworms	Improve cotton prod.	Pink bollworm control	Insect pest suppression
Ref. Page	A-46 ff.	C-6 ff.	C-21 ff.	C-42 ff.	C-43 ff.
Year Started	1972	1950	1972	1968	1971
Area	3 Parishes	6 counties	3 counties	1 county	1 county
Acres)	5,600	200,000	19,000	4,492	31,508
Farms) in	70		101	35	85
Fields) PM	230				
# Scouts	6		13[5/]		46
# Scout Supv.			7[5/]		12
Acres/Scout	933				
Pest Mgmt. Acreage Ratio	10% of Cotton Acreage in area	22% in San Joaquin V.	3% in 3 counties	About 25% of the county	
Insect Management Costs, $	per Acre (1972)	per Acre (1971)	per Acre	per Acre (1971)	per Acre (1972)
Scouts	2.45*	2.33	1.30 -17.00	1.65	1.00
Scout Travel					
Scout Supv.					
Co. Agents					
Prof. Support					
Other					
Subtotal					
Insecticides	17.24	4.20		13.50	26.35
Application	10.90				
Total	30.59	6.53		15.15	27.35
Growers'Funds	28.14	6.53	2.00-2.50[5/]	15.15	27.35
Public Funds*	2.45	--	2.00-3.00* 3/5/		
Benefits:					
Cotton Yield	No data[10/]	+.16 to .43 bale	Insufficient data	Insufficient data	Insufficient data
Insectic. Use	No data[10/]	- $3 to 11	- $5 to 10	Decreased	- $11 to 14
Product. Cost	No data[10/]	- $1 to 9	- $3 to 8	Insuff. data	- $10 to 13
Profit	No data[10/]	+ $16 to 65	+ $3 to 8 ± chg. in yield	Insuff. data	+ $10 to 13 ± chg. in yield

Notes on page 56

Table 3 : Characteristics, Costs and Benefits of 19 Cotton Pest Management Programs, 1973[1/]

Program	T e x a s				
Location	High Plains	Glasscock County	South TX Rio Grande Valley	Pecos Research Station	East Texas, TX Dept. of Corrections
Purpose	Diapause boll weevil suppression		Avoid Heliothis damage	Insect pest suppression (demonstration)	
Ref. Page	D-6 ff.	D-23 ff.	D-34 ff.	D-45 ff.	D-56 ff.
Year Started	1964	1968	1973	1968	1970
Area	Several co.'s	1 county	3 counties	2 counties	Several co.'s
Acres) Farms) in PM Fields)	186,000 (1972)	16,200	23,000		5,757 (1972)
# Scouts					
# Scout Supv.					
Acres/Scout					
Pest Mgmt. Acreage Ratio		100% in proj. area	10-15% in proj. area		
Insect Management Costs, $	Entire Program	per Acre	per Acre	per Acre	per Acre
Scouts			5.00	5.00	5.00
Scout Travel					
Scout Supv.	172,180				
Co. Agents					
Prof. Support					
Other	85,313*				
	68,142				
Subtotal	325,635				
Insecticides	449,738				
Application	136,195		18.77	0.00	3.78
Total	911,568	1.51			
Growers' Funds	413,127	0.76	23.77		
Public Funds*	498,441*	0.75*			
Benefits:					
Cotton Yield	+ 4.0%	No change	No change	+ 28.3%	+ 19.1%
Insectic. Use	- 82%	- 83%	- 33.7%	- 86.0%	- 50.2%
Product. Cost	- 8.2%	- 3.7%	- 6.8%	- 13.0%	- 0.5%
Profit	+ 8%	+12.0%	+57.3%	+100.0%	+143.1%

Notes on page 56

Table 3 : Characteristics, Costs and Benefits of 19
Cotton Pest Management Programs, 1973[1/]

Program	Texas			
Location	Rio Grande Valley	Blacklands Hill and Ellis co.'s	Trans-Pecos Reeves and Pecos co.'s	**Frio Co. & neighboring counties**
Purpose	Insect pest suppression; cotton production improvement			
Ref. Page	D-76, 88 ff.	D-99, 108 ff.	D-120, 130 ff.	D-141, 151 ff.
Year Started	1972	1972	1972	1971
Area	3 counties	2 counties	2 counties	1 county
Acres) in IPM	15,632	10,266	8,600	1,422
Farms) in IPM	77	59	28	20
Fields) in IPM		208	134	28
# Scouts	12	7	9	-
# Scout Supv.				
Acres/Scout	1,303	1,467		
Pest Mgmt. Acreage Ratio	5% in project area	Near 100% in project area	25% in project area	100% in the county
Insect Management Costs, $	Entire Program	Entire Program	Entire Program	Entire Program
Scouts	18,771	9,317	9,558	--
Scout Travel	4,552	1,405	2,078	--
Scout Supv. Co. Agents[2/]	21,817	16,659	28,588*	18,879*
Prof. Support Other	3,010	2,625	4,606*	1,424*
Subtotal	48,150	30,006	44,830	20,303*
Insecticides Application				
Total				
Growers' Funds	3,933	5,865	13,555	--
Public Funds*	36,792*[3/] 7,425*[4/]	20,941*[3/] 3,200*[4/]	21,275*[3/] 10,000*[4/]	15,053*[3/] 5,250*[4/]
Benefits:				
Cotton Yield	+ 25.1%	+ 11.5%	+ 6.1%	+ 0.9%
Insectic. Use	+ 11.4%	- 30.0%	+ 2.0%	-25.4%
Product. Cost	+ 5.0%	- 2.8%	- 3.0%	+ 2.9%
Profit	+112.5%	+ 23.9%	+36.5%	- 6.0%

Notes on page 56

Footnotes pertaining to Table 3:

* Public funds

1/ Unless another year specified

2/ Incl. travel costs

3/ Federal (USDA) funds

4/ State funds

5/ Data from USDA Summary for 1973

6/ Decrease only in 1973, 6-year average shows no decrease

7/ Increase due to scouting costs less reduced costs of insecticides

8/ Midpoint of range of yield increases, 96 to 363 lb/acre

9/ Approximate savings relative to other producers in the area for the same year, based on average cost per insecticide application of $2.26/acre

10/ Only 30% of producers in program followed scouting recommendations an estimated 18% of the state's total cotton acreage.

Initially, the Arkansas program was a "prescription insecticide program" (refer to the discussion of different types of cotton insect control programs per Newsom, as relayed by Parvin, p. A-19 ff.). Beginning in 1968, cotton growth monitoring was added, and field-checking and monitoring of traps and sugar lines for additional insects have recently been added. In addition, Arkansas has for many years provided grower pest management training by scouting schools, radio and TV programs, county insect letters, and county pest management demonstrations. It is estimated that today, 40-50% of all Arkansas cotton growers (and/or their families) scout their own fields, that 80% of all Arkansas cotton acres are scouted, and that practically all cotton growers in the state apply at least some pest management principles. Thus, there are practically no "controls" or "non-pest management" cotton areas in the state.

As described in greater detail by Carlson and Grube (p. B-2ff.), the infusion of USDA funds into the Arkansas cotton pest management program came at a very opportune time. These funds were used primarily to imporve scout supervision and thus the quality of the scouting program. This has reinvigorated growers' confidence in the program and was instrumental in bringing additional acreage under pest management.

California: The "pest management consultants" program in California has almost as long a history as the Arkansas pest management program. It started in about 1950, based on research by, and guided by University of California entomologists. In 1973, private pest management consultants serviced an estimated 200,000 acres of cotton in California's San Joaquin Valley, that is about 22% of the total acreage in the Valley. (For further details, see Norgaard, p. C-6 ff. of this report). Initially, California's "supervised insect control" revolved around the management of the key pest insects on California cotton, the lygus bug, *Lygus hesperus*, and the bollworm, Heliothis zea. Today, some private consultants' services are still limited to counting insects and making treatment recommendations to the growers, while others have adopted a more comprehensive crop management (as opposed to insect management) approach. This development received considerable added impetus with California's participation in the USDA/State-supported cotton pest management program in 1972. Systematic monitoring of cotton development, and development of dynamic economic thresholds for lygus were included in the California "scout program" beginning in 1972 (Norgaard, p. C-21 ff.; Falcon, 1972; Smith and Falcon, 1973).

In this program, the Cooperative Extension Service in California engaged the services of private pest management consultants. In this manner, the total cotton acreage under pest management was extended more rapidly than would have been the case otherwise, while at the same time, private-enterprise pest management consulting received a substantial boost, instead of possible competition from a publicly financed pest management program.

Texas High Plains: This program, comprising 186,000 acres in 1973, is aimed at boll weevil suppression, as reported in detail by Lacewell and Casey (p. D-6 ff.). This program was initiated in 1964 with the objective of preventing further spread of the boll weevil. The program was instigated by a cotton grower organization, Plains Cotton Growers, Inc., and was implemented jointly by this organization and Texas A & M University, Texas Tech University, and the U.S. Department of Agriculture. The program essentially accomplished its initial purpose of suppressing boll weevil populations in the High and Rolling Plains of Texas. In 1970, about 360,000 acres of cotton received a total of 1,170,000 acre-treatment with insecticides for diapause boll weevil control. In 1972, the "base acreage" in the program declined to 186,000 acres.

A second, much smaller diapause boll weevil control program in Texas is in Glasscock County. It covered about 16,200 acres in 1973. For further details, see Lacewell and Casey, p. D-23 ff.

Alabama: The Alabama pest management program is the fourth largest in acreage among those studied in this project. In 1973, it covered 115,000 acres on 599 farms in 17 counties; employing 73 scouts. This represents a rapid expansion from about 39,000 acres under the same program in 1972. In Alabama, as in other cotton states in the Midsouth, the key pest of cotton is the boll weevil. A characterization of key pests, occasional pests, and secondary pests of cotton in the Midsouth, and of the relationships between these insect pests and the development of the cotton crop has been provided by Parvin (p. A-2ff.). Details of the Alabama pest management programs (1972 and 1973) have been documented and analyzed by Parvin (p. A-36 to A-45).

Mississippi: The Missippi pest management program is very similar to that in Alabama. It also started in 1972 and covered 13,827 acres in 1973, its second year of operation. Details on both program years for Mississippi are provided by Parvin, p. A-25 to A-35.

North Carolina: Organized cotton pest management activities started in about 1967 in North Carolina. In 1974, 11 farmer-directed pest control cooperatives and 3 commercial firms were actively involved in cotton pest management in the state. The acreage under these programs grew from a few thousand in 1967 to about 50,000 acres in 1973, and to 76,000 acres in 1974. In 1973, 459 farms were involved, and 47 scouts were employed (for further details, see Carlson and Grube, p. B-3 ff., B-13 ff., B-42 ff.).

The cooperatives, also known as "spray groups", serve several insect control functions. They provide scouting, aerial applicator services, insecticide purchase in bulk, bookkeeping insect trap monitoring, and insecticide use decisions. The latter are made either by individual managers (farmers and/or persons trained in entomology), or by some or all members of the board of directors. Cooperative members transfer rights and responsibility for insect control to the cooperative. Most of these groups operate on an area-wide basis. As described in greater detail by Carlson and Grube (p. B-13 to B-21), the cooperatives vary considerably in number of years of experience, acreage covered, number of members, number of scouts employed, and operating and decision-making procedures.

The USDA-supported North Carolina cotton pest management pilot project worked with 6 of these cooperatives in 1973, covering about 24,000 acres of cotton. Federal project funds were used to furnish each group a scout supervisor, personnel to collect background data, forms to record scouting results, clerks to transcribe data, computer programming, and data processing. Varying degrees of guidance on the operation of scouting programs and the use of insecticides were provided by project personnel. In this manner, federal funds in North Carolina (as in California) were used to upgrade and expand existing private-enterprise cotton pest management activities.

In addition to these cooperatives, three commercial cotton pest management organizations operated in North Carolina in 1973. At least two of them have been in business for a number of years. For further details, see Carlson and Grube, p. B-21.

Texas: Among all states studied in this project, Texas appears to have the largest number and variety of cotton pest management programs. The program characteristics, users and locations, all operating details, and effectiveness, costs and returns have been documented and evaluated in great detail by Lacewell and Casey (Appendix D of this report). Their evaluation covers 9 individual cotton pest management programs; 4 of these are part of the USDA-supported "Texas scout" or Texas cotton insect management program.

The diapause boll weevil suppression programs in the Texas High Plains and in Glasscock County have already been mentioned. In 1973, the remaining 7 Texas pest management programs combined covered about 65,000 acres on more than 200 farms in 16 counties, employing 28 scouts. Program users include the Pecos Research Station, the Texas Department of Corrections, and several groups of individual growers in areas ranging in size from 1 to 3 counties. Purposes of these programs include demonstration of the feasibility of pest management (in contrast to unilateral reliance on chemical insecticides); avoidance of damage by cotton bollworms (especially Heliothis virescens) through the use of short-season, early maturing, determinate cotton cultivars which permit cotton harvest before these insects become economically damaging; general cotton insect pest suppression; and cotton production improvement.

Lacewell and Casey (p. D-4 to D-5) point out that beyond the publicly supported pest management programs in Texas, there is considerable activity in pest management consulting in the private sector. Approximately 30 entomologists who are members of the Texas Association of Consulting Entomologists provide cotton growers with pest management advice. In addition, there are 15 to 20 insect scouts who, while not members of the Association, work as private consultants to producers relative to cotton insect population control. It is estimated that about 300,000 to 400,000 acres of crops are scouted annually in Texas by private consultants.

Louisiana: This program was initiated in 1972, and the only information available on the program is for the 1972 crop season. This program, one of those in the USDA/State Cooperative Program, was conducted in portions of Catahoula, Grant and Tensas parishes; these parishes are representative of major cotton farming areas in Louisiana. In 1972, 70 producers and 5,600 acres participated in the program, and 6 scouts were employed.

PROGRAM COSTS

The quality and quantity of data available on the types and amounts of costs associated with the establishment and operation of pest management programs vary widely for the different programs evaluated in this study. Carlson and Grube (Appendix B) accumulated and analyzed a great volume of cost data from the Arkansas pest management program (dating back as far as 1960), and for some of the North Carolina pest management cooperatives.

However, in both the Arkansas and North Carolina programs reviewed, there is no delineation between establishment or start-up costs and ongoing operating costs. In both instances, the programs started small, essentially by "self-ignition", and developed to their present dimensions gradually, over about 25 years in the case of Arkansas, and over several years in the case of the North Carolina programs.

Operating cost data for 1973 for these Arkansas and North Carolina programs are included in Table 3 . Many further details, including information for prior years, are reported in Carlson and Grube's complete account in Appendix B.

Very good, detailed operating cost data are available for most of the Texas programs for 1972 and 1973 (Lacewell and Casey, Appendix D). Again, only data for 1973 have been included in Table 3 , and the reader is referred to Lacewell and Casey's report for further details, and for data for 1972 and earlier years.

The Texas report is the only one that provides program cost details broken down by implementation costs, annual overhead, annual operating costs, and state-level implementation, coordination and operating costs. For each year of the program, Lacewell and Casey provide the following details:

> Implementation costs broken down by items, including mapping, grower contact, recruitment, and scout training; and by source of funds, separated by federal and state funds.
>
> Operating (program) costs broken down by items, including salaries for county extension personnel, scouts, and clerical help; travel expenses for county extension personnel and scouts; and supplies, miscellaneous, and incidentals. Source of funds by items is broken down by 3 categories, i.e., federal funds (USDA grant), state funds (Texas Agricultural Extension Service), and producer contributions.

State implementation, coordination and operating costs broken down by items and source of funds.

Estimated implementation and operating costs for 7 regional pest management programs in Texas are summarized in Table 4 .

Much less detail on program costs is available from the Mississippi, Alabama, Louisiana, California, and Arizona programs.

As the data summarized in Table 3 for 1973 indicate, the costs of the different programs varied considerably. Scouting costs (including scout salaries and travel expenses) ranged from $1.05 per acre in Arkansas to $5.00/acre in several Texas programs, and up to more than $10/acre in the California scout program (which includes plant growth measurements, in addition to insect counts). A tabular comparison of costs for scouting only follows:

Arkansas	$1.05/acre
North Carolina	1.18/acre
Mississippi	1.25/acre
Alabama	1.25/acre
Arizona	1.00-1.65/acre
Louisiana	2.45/acre
Texas	5.00/acre

Costs of scout supervision, county agents or extension entomologists contributing to programs, professional support, and other items (clerical and computer time, supplies, etc.), are given only in a few instances, some per acre, some for entire programs.

From the data summarized in Table 3 , ratios of overhead costs (including scout supervision; county agents/extension entomologists; professional support; and "other") to scouting costs (scout salaries and travel) have been computed for those programs for which adequate data are available (Table 5). Arkansas had by far the lowest supervision and overhead costs (1 : 0.5), followed by Texas' Rio Grande (1 : 1.1) and Blacklands (1 : 1.8) programs. In North Carolina and in Texas' Trans-Pecos programs, cost of supervision and overhead were almost 3 times as high as the scouting costs.

Table 4 : Estimated Implementation and Operating Costs for Regional Pest Management Programs on Cotton in Texas

Program	Implementation Costs[1/]	Operating Costs/Year
High Plains	\$70,000 - 100,000	\$600,000 - 1,350,000
Glasscock Co.	18,000	11,000 - 100,000
East Texas	Nil	2,000
Rio Grande Valley	13,000 - 48,386	48,150
Blacklands	9,500 - 27,555	30,006
Trans Pecos	1,800 - 17,479	44,830
Frio County	1,100 - 13,397	20,303

1/ The ranges given include estimated implementation costs in the low value, and implementation plus first year operating costs in the high value since so much of the first year's efforts were directed to program organization and development.

Source: Lacewell, R. D. (1975)

Table 5: Comparison of Scouting Costs vs. Costs of Supervision and Overhead for Selected Cotton Pest Management Programs, 1973

Program	Unit	Scouting[1]	Supv. & Overhead[2]	Scouting Costs: Supv. & Overhead
Arkansas[3]	per Acre	$ 1.05	$ 0.52	1 : 0.5
N. Carolina[4]	per Acre	1.18	3.41	1 : 2.9
Texas				
- Rio Grande[5]	Program	$23,323	$24,827	1 : 1.1
- Blacklands[6]	Program	10,722	19,284	1 : 1.8
- Trans-Pecos[7]	Program	11,636	33,194	1 : 2.9

1/ Incl. scout salaries and travel

2/ Incl. scout supervisors; county agents/extension personnel (salaries and travel); professional support; clerical and computer time

Sources:

3/ Carlson and Grube, p. B-41

4/ Carlson and Grube, p. B-45

5/ Lacewell and Casey, p. D-91

6/ Lacewell and Casey, p. D-106

7/ Lacewell and Casey, p. D-127

The detailed reports on these programs indicate that in the Arkansas program, scout supervision may be suboptimal. The North Carolina costs of supervision and overhead are so high because the USDA grant funds were used to beef up already existing supervision, and to provide data collection and processing for previously established programs. The supervision and overhead costs in the Texas Trans-Pecos program are relatively high because the county extension entomologist carries out most of the field scouting responsibilities.

In summary, this report provides detailed implementation cost data for 6 of the 9 regional cotton pest management programs in Texas, and operating cost data for all programs evaluated. The majority of the operating cost data are detailed and broken down by items such as salaries, supervision, materials and supplies, etc., and also by source of funds (Federal, State, grower contributions, etc.). The operating cost data provided go back to 1960 for the Arkansas program, to 1964 for the Texas High Plains program, and to 1968 for the Glasscock County, Texas program. For most other programs, operating cost experiences are reported for 1972 and 1973. Table 3 includes 1973 operating cost data by items and by source of funds for all cotton pest management programs studied to the extent that the authors of the 4 regional reports (Appendix A - D) were able to obtain this information. Table 4 (p. 64) summarizes estimated implementation and annual operating costs for 7 Texas programs, and Table 5 (p. 65) compares scouting costs with cost of supervision and overhead for 5 of the programs studied.

PROGRAM EFFECTIVENESS

The effectiveness of cotton pest management programs was measured by several different criteria, including:

- -- Cotton yields,
- -- Pesticide use,
- -- Production costs,
- -- Profit to growers.

An effort to evaluate the 1972 USDA/State-sponsored cotton pest management programs has been undertaken by Womach (1974). Cotton project questionnaires for evaluation of the 1972 program were sent to project leaders in the latter part of 1973. Question forms were returned and tabulated in the spring and summer of 1974. Womach's report includes data, all for 1972 by states, on the following items:

Cotton acres planted,
Program participation,
Scouting activities (numbers of scouts, acreage scouted, fields scouted, acres per scout, fields per scout),
Numbers of scout supervisors,
Time lapse between scouting and recommendations to producers,
Degree of producers' compliance with program pest control recommendations,
Contributions from private consultants, industry representatives, and regulatory agencies in the pest management programs,
Cost items (professional support, scout supervisors, scouts, clerical, computer, supplies, totals),
Sources of funds (USDA, state, grower, totals),
Producer contributions per acre and as a percent of scouting costs,
Program costs per acre scouted,
Percent of 1972 producers who agreed to participate in 1973,

Number of pest management organizations in the pest management project areas,

Cotton yields for participating and non-participating growers (only 11 of 14 states provided yield data for program participants, and only 4 of the 14 states provided yield estimates for non-participants),

Pesticide application rates and costs for program participants,

Target pests,

Number of economic threshold infestations and number of pesticide applications,

Insecticides used most frequently,

Effects of diapause boll weevil control on pesticide use,

Measures of scout safety.

Womach concluded in part as follows:

"From the first year's data, it is not possible to draw any firm conclusions about the cotton pest management program's effects upon economic efficiency or environmental quality. The limited information available indicates that in some states positive benefits did result. Several factors contributed to the lack of evidence in 1972 on the benefits of the program. First of all, and most important, the designers and leaders of the program did not or could not build in a control sample to serve as a comparison group with the cooperating producers. It is recognized that adequate control samples are difficult to obtain because of the large acreage involved and the diversity of pest and cultural conditions. Secondly, prior to initiation of the program little information was available to document and assess the size and severity of environmental and economic problems related to pest control and pesticide use. Finally, as the initial year of a three-year program, 1972 does not serve as an entirely valid indicator for the success of the program".

Analysis of all 19 pest management programs evaluated in this study indicates that most of them suffer, although in varying degrees, from the same deficiency, i.e., lack of planning and provision for meaningful measurements of program effectiveness and comparisons between program participants and non-participants. By far the most useful data in this regard come from the Texas programs as documented by Lacewell and Casey in Appendix D. They report, for each year of most Texas programs, cotton yields (lint, seed, and totals), insecticide inputs, production costs (variable pre-harvest and harvest costs, fixed costs, and totals), and net returns. These data are given for participating growers and for carefully selected, reasonably comparable non-participating growers.

Carlson and Grube (Appendix B) were able to supply some actual yield comparisons between pest management cooperative members and non-members in North Carolina. As already mentioned above, comparing Arkansas farmers who use pest management to those who do not is impractical because essentially all Arkansas cotton growers apply at least some pest management principles. In the absence of possibilitties for direct comparisons, Carlson and Grube evaluated the effect of scouting on early season insecticide treatments, and the effect of infestation records on marginal productivities of insecticides (p. B-22 ff.).

In the report on Mississippi, Alabama and Louisiana, Parvin (Appendix A) compared the quantities and costs of insecticides actually used in 1972 and 1973 by pest management program participants to a "norm", derived from the approximate costs of producing cotton in the Midsouth for producers using a calendar or "womb to tomb"-insecticide program (for further details, see p. A-51 ff.).

Criteria employed by Norgaard for measuring the effectiveness of the cotton pest management programs in California and Arizona include cotton yields by quantity and by value, and total pest management costs including pesticides, application and consulting fees. These data are compared for pest management program participants and non-participants, or for averages for the program compared to appropriate county averages.

Data on pest management benefits for all programs evaluated, including effects on cotton yield, insecticide use, production costs and growers' profits for 1973 are summarized in the lower part of Table 3 , p. 52-55.

The differences in the quantity and quality of the available data on program benefits made quantification of these benefits a very difficult task. It was not possible to present all benefit data in terms of one common denominator; instead, some are given in terms of percent, some in terms of dollar values.

Effects on yield

Cotton yield increases in 1973 were reported in 11 of 13 programs for which yield data are available, i.e., Arkansas, North Carolina, Alabama, California (private consultants), and in 7 programs in Texas.

In 2 programs, i.e., Glasscock County, Texas, and South Texas, there were no changes in yield. In both of these programs, the program objective was to prevent yield decreases from infestations of the bollweevil (Glasscock County) or from bollworms (South Texas program). Therefore, "no decrease", or "no change" (in yield) in these cases means that the program was successful.

No information on yield effects was available from the remaining 5 programs, i.e., Mississippi, Louisiana, the California "scout program", and both Arizona programs.

Quantifiable yield increases ranged from + 0.9 to + 28.3%, and from about 80 to 230 lbs. of cotton per acre. (For further details, refer to Table 3 , p. 52-55.

Effects on insecticide use

Fourteen of the 17 pest management programs for which insecticide use data are available reported decreases in the quantities of insecticides used on cotton under pest management, i.e., Arkansas, Mississippi, Alabama, both California and both Arizona programs, and 7 Texas programs. Two Texas programs (Rio Grande

Valley and Trans Pecos) reported increased use of insecticide per acre, but insecticide use per pound of cotton produced declined. Increased insecticide use was also experienced in the North Carolina programs, suggesting that insecticide use may have been suboptimal in areas not under pest management.

In the 14 programs where the use of insecticides decreased, reductions were within the following ranges: 20 to 86%, \$3 to 14/acre, or 2 to 4 insecticide applications/year. Insecticide use increases ranged from 2 to 24%.

Effects on production costs

Production cost changes can be caused in several different ways by pest management programs. Production costs may increase by the cost of the pest management program, decrease by savings in pesticide inputs, or move in either direction by combinations of these factors.

Among the pest management programs evaluated, 7 of 9 Texas programs and 6 others experienced net decreases in production costs; the latter included Arkansas, Mississippi, Alabama, both California programs, and Pinal County, Arizona. Production cost decreases from adoption of pest management practices ranged from 1 to 13%, or form \$1 to 13/acre.

There was an increase in production costs in 3 programs, i.e., North Carolina (+ \$10/acre), Rio Grande Valley Texas (+5.0%), and Frio County, Texas (+ 2.9%).

No adequate data on production costs were available for the remaining 2 programs, i.e., Louisiana, and Graham County, Arizona.

Effects on growers' profits

From the cotton producers' standpoint, this is undoubtedly the most important indicator of the degree of success of cotton pest management programs. It is therefore significant that the effectiveness of the cotton pest management programs evaluated was most clearly demonstrated by this criterion.

Fifteen of the 16 programs for which adequate data are available resulted in increased profits to growers, i.e., all programs

except Frio County, Texas, which experienced a decrease in growers' profits of 6% in 1973, and the Louisiana and Graham County, Arizona programs for which available data are insufficient. Quantifiable profit increases ranged from 9 to 112.5%, or from $3 to 84/acre. (For further details, refer to Table 3, p. 52-56.)

In summary, the effects of the pest management programs evaluated on cotton yields, insecticide use, production costs and growers' profits were as follows, expressed in numbers of programs in each category:

Effect	*Yield*	*Insecticide Use*	*Production costs*	*Growers' profit*
Increase	11	3	3	15
Decrease	-	14	13	1
No change	2	-	-	-
No data	5	1	2	2
Totals	18	18	18	18

These program effects are summarized in the preceding section on program effectiveness, and tabulated in quantified form (to the extent available) in Table 3 , p. 52 ff. Detailed discussions of these pest management program benefits for 1973, the base year for Table 3 (except as indicated), and for additional program years are presented in the regional studies, Appendices A through D. For easy access to these detailed data in the appendices, Table 3 includes references to the Appendix page numbers for each of the programs evaluated.

These findings concerning the effectiveness of cotton pest management programs are very significant and encouraging. It is somewhat surprising that these practical effectiveness indicators have not been more thoroughly studied, and that they have not been widely utilized and publicized. Data such as those summarized in this section, especially *data on increased profits, will "sell" pest management to farmers far more effectively than other measures.*

CONSTRAINTS ON EXPANSION OF COTTON PEST MANAGEMENT PROGRAMS

In accordance with the objectives of this study as set forth above (p. 2-3), all of the authors of the regional reports addressed the question of constraints on the expansion of the cotton pest management programs which they studied. Some of these have already been covered in whole or in part in the general discussion on this topic above (p. 32-42) but each regional investigator's comments are summarized below in order to provide a complete, coherent account of their views.

Parvin (p. A-29) mentions the following "potential roadblocks" to the successful further development of the pest management concept:

-- lack of sufficient numbers of trained personnel;

-- current attitudes of the insecticide industry, commercial applicators and growers;

-- cooperation between members of all disciplines involved in crop production;

-- difficulties in developing and registering for use insecticides that are especially needed in pest management;

-- convincing producers to accept the economic threshold concept, obtaining information on their insecticide applications, and satisfying their request for more personal attention by project staff;

-- early termination of the scouting program as a result of early fall school starts.

Carlson and Grube (p. B-54 ff.) point out that in Arkansas, ineffective scout recommendations were threatening to restrict further expansion of the cotton pest management program. However, this has been at least partially corrected in the past few years with the increase of scout supervision made possible through the USDA funds. In addition, they mention the following problems:

Arkansas:

-- inadequate support of the pest management program, especially scout training, on the part of county agents in many cotton counties;

-- inadequate understanding of the program by many growers, aerial applicators and insecticide sales firms;

-- inadequate use of the extensive information collected by scouts and compiled in computers;

North Carolina:

-- shortage of trained and experienced pest management leaders in the cooperatives;

-- lack of adequate scout supervision when cooperatives become too large;

-- inadequate cotton insect warning systems (insufficient use of light traps, sugar lines, radio announcements, and other warnings, especially in regard to bollworms;

-- combination of pest management with chemical and application services which may result in higher insecticide use than necessary.

Norgaard (p. C-49 ff.), based on his evaluation of the California and Arizona cotton programs, mentions the following constraints:

-- inadequate demonstration and advertising of the economic advantages of pest management by government agencies in California, despite ample justification in terms of health, safety, and environmental quality;

-- inadequate exploitation and implementation of available economic data;

-- high cost per acre of delivering pest management to small fields.

Lacewell and Casey's comprehensive report does not include an item on "constraints"; instead, they approach the problem from the positive side and entitle the section in question "components of a successful program" (p. D-190 ff). The following items are included in this category:

- program support by a strong producer organization;
- strong individual producer support of the program, coordinated through the producer group or association;
- County extension entomologists possessing above-average competence, initiative, enthusiasm and ability;
- a strong research component developing optimum pest management strategies and new and innovative approaches in all phases of cotton production, oriented toward local or regional climatic and other requirements, and effective flow of information between research and implementation;
- continued governmental support, justified by documentation of actual and potential benefits to producers as well as to society.

PEANUT PEST MANAGEMENT PROGRAMS

BACKGROUND

Peanuts are beset with a variety of pest problems. Insect pests of peanuts include the lesser cornstalk borer (*Elasmopalpus lignosellus*), the red-neck peanut worm (*Stegasta bosquella*), the burrowing bug (*Pangaeus bilineatus*), and several foliage-feeding insects. Economically important fungus diseases of peanuts include Cercospora leaf spots (*Cercospora arachidicola* and *C. personata*), Southern blight (*Sclerotium rolfsii*), and several soil-borne pathogens including *Pythium*, *Rhizoctonia*, and *Fusarium* species. In addition, peanuts are attacked by several species of nematodes including the root-knot nematode (*Meloidogyne* sp.) and the root lesion nematode (*Pratylenchus brachyurus*). A variety of weeds can also be a problem, especially in irrigated peanuts. The occurrence and severity of these pests vary considerably between different peanut growing areas.

To a greater or lesser degree, commercial peanut growers in the U.S., especially in Virginia and Georgia, have practiced pest management out of practical necessity for many years before the term became widely known and used. Organized pest management programs on peanuts were initiated under the auspices of the USDA/State cooperative pest management program in Comanche County, Texas and in 3 counties in Oklahoma in 1973. Lacewell and Casey (Appendix E of this report) evaluated one additional peanut pest management program in Texas, i.e., one started by private initiative in Frio County in 1971.

A workshop on peanut and tobacco pest management, sponsored jointly by the Cooperative Extension Service and Oklahoma State University, was held at Oklahoma City, Oklahoma in February of 1974. At this meeting, peanut and tobacco pest management strategies and tactics were discussed, including the progress in specific projects, use of remote sensing techniques, data collection and handling procedures, grower support, economic thresholds for insects, nematodes, and diseases of peanuts, and monitoring for pesticides. The workshop proceedings include a brief progress report on the pest management project in Comanche County, Texas, for 1973 by Hines and Hoelscher (1974), and a very comprehensive, detailed report on Oklahoma's 1973 peanut pest management activities by Sturgeon et al. (1974).

TRENDS IN PEANUT PRODUCTION AND PESTICIDE USE

In the United States, peanuts were harvested for nuts on about 1.5 million acres in 1973. The geographic distribution of this peanut acreage was as follows: 269,000 acres in the Virginia-North Carolina area; 792,000 acres in the Southeast (including South Carolina, Georgia, Florida, Alabama, and Mississippi), and 435,000 acres in Oklahoma, Texas, and New Mexico. For the entire U.S., the average yield per acre of peanuts harvested in 1973 was 2,323 lbs. Farmers received an average price of $0.162/lb. Total U.S. peanut production in 1973 was about 3.5 billion lbs., worth about $560 million at the farm level, or about $375/acre (U.S. Department of Agriculture, 1974d).

The use of fungicides, insecticides and herbicides on peanuts in 1966 and 1971, and the U.S. peanut acreage in 1964, 1966 and 1971 are summarized in Table 6. Pesticide use data are available only for the years 1966 and 1971, from surveys of the quantities of pesticides used by farmers conducted by the U.S. Department of Agriculture for these years. In a similar USDA survey covering 1964, peanuts were not disaggregated, and farm pesticide uses have not been surveyed since 1971. No data on the quantities of nematicides used on peanuts are available for any of the years covered by the USDA farm pesticide use surveys.

The total U.S. peanut acreage increased slightly from 1964 to 1971, from about 1.4 million acres in 1964 to 1.46 million acres in 1971. In 1973, 1,496 million acres of peanuts were grown, an increase of about 7% over 1964 (USDA, 1974d).

The use of insecticides on peanuts increased slightly from 1966 to 1971, i.e., from 5.5 million lbs. of active ingredients (AI) in 1966 (3.9 lbs. AI/acre) to almost 6 million lbs. (4.1 lbs. AI/acre) in 1971.

Table 6 : U. S. Peanut Acreage and Use of Insecticides, Fungicides and Herbicides on Peanuts, 1964 - 1973

Year	1964	1966	1971
Peanut Acreage 1/ (1,000 Acres)	1,397	1,418	1,455
Pesticide Use on Peanuts			
Insecticides			
- Total (1,000 lbs. AI)	N.a.	5,529	5,993
- per Acre (lbs. AI)	N.a.	3.9	4.1
Fungicides 1/			
- Total (1,000 lbs. AI)	N.a.	1,108	4,431
- per Acre (lbs. AI)	N.a.	0.8	3.1
Herbicides			
- Total (1,000 lbs. AI)	N.a.	2,899	4,374
- per Acre (lbs. AI)	N.a.	2.0	3.0
Nematicides	N.a.	N.a.	N.a.
Fungicides, Insecticides and Herbicides 1/			
- Total	N.a.	9,536	14,798
- per Acre	N.a.	6.7	10.2

1/ Acreage harvested for nuts

2/ Excl. sulfur

Sources: U. S. Department of Agriculture (1968b, 1968c, 1970, 1973a, 1974a)

The use of fungicides almost quadrupled from 1966 to 1971, i.e., from 1.1 million lbs. of active ingredients (0.8 lb. AI per acre) in 1966 to 4.4 million lbs. (3.1 lbs. AI/acre) in 1971.

The use of herbicides on peanuts increased by about 50% from 1966 to 1971, i.e., from 2.9 million lbs. of active ingredients (2.0 lbs. AI/acre) in 1966 to 4.4 million lbs. (3.0 lbs. AI/acre) in 1971.

The combined volume of fungicides, insecticides and herbicides used on peanuts amounted to 9.5 million lbs. of active ingredients (6.7 lbs. AI/acre) in 1966, increasing to 14.8 million lbs. (10.2 lbs. AI/acre) in 1971. These data indicate that the production of peanuts in the United States involves rather heavy annual inputs of chemical pesticides.

USERS, LOCATIONS, AND CHARACTERISTICS OF THE PROGRAMS STUDIED

In this project, 3 peanut pest management programs were studied. The location of these programs, superimposed on a dot-map of the U.S. peanut acreage harvested for nuts in 1969 (the latest year for which such dot-maps are available), are given in Figure 2.

Table 7 provides an overview of the characteristics, costs and benefits of the 3 peanut pest management programs evaluated in detail by Lacewell and Casey (Appendix E), including program location; objectives; starting year; area; acres, farms and fields in the program; number of scouts and scout loads; program costs; source of funds; and benefits obtained. The entries opposite "Ref(erence) Page" refer to the page numbers in Appendix E where these programs are described and analyzed in detail. The data in Table 7 pertain to the year 1973. For 2 of the 3 programs, this was the starting year. Important features of the 3 programs are as follows.

Frio County, Texas Program: This program was initiated in 1971 under the direction of the Frio County Peanut Improvement Association, with assistance from the Texas Agricultural Experiment Station and Extension Service. This program is focused on

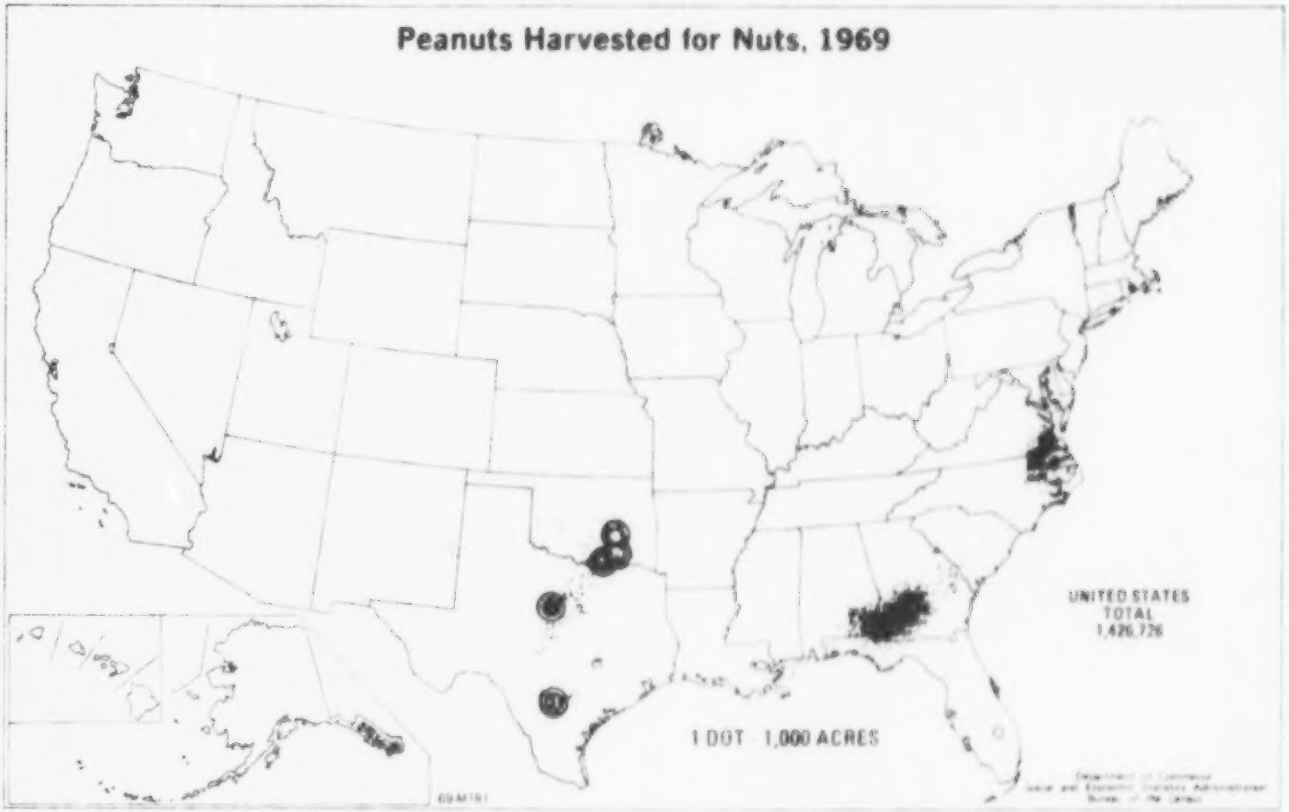
Peanuts Harvested for Nuts, 1969
UNITED STATES
TOTAL
1,426,726
1 DOT 1,000 ACRES
69M191
Department of Commerce
Social and Economic Statistics Administration
Bureau of the Census

Figure 2: Locations of the Peanut Pest Management Programs Evaluated in this Report Relative to the Geographic Distribution of Peanut Acreage in the U.S.
(Program locations indicated by circles)

Table 7 : Characteristics, Costs and Benefits of 3 Peanut Pest Management Programs, 1973

Program Location	Frio County, Texas	Comanche County, Texas	Atoka, Hughes & Marshall Co., Okla.
Objective	Insect pest suppression	Insect pest suppression[3]	Plant health improvement
Ref. Page	E-3 to 18	E-19 to 38	E-39 to 56
Year started	1971	1973	1973
Area	1 County	1 County	3 Counties
Acres) in IPM	6,558	1,315	394
Farms) in IPM	23	33	8
Fields) in IPM		42	
# Scouts	4	3	1 team
Acres/Scout	1,640	435	
IPM Acreage Ratio	Abt. 30% of peanut acres in the county	Abt. 2% of peanut acres in the County	40% of peanut acreage of particip'g farms
Pest Management Costs, $	Entire program[2]	Entire program	Entire program
Scouts	6,558	2,686	1,500
Scout Travel		879	
Extension Service	765	20,187	5,600
Professional Support	459	13,000	8,100
Other[1]	100	3,381	5,800
Total	7,882 (1.20/acre)	40,133 (28.77/acre[4])	21,000 (53.16/acre)
Source of Funds, $			
Grower Funds	6,558 (1.00/acre)	300 (0.25/acre)	-
State Funds	1,324 (0.20/acre)	26,850	8,600
Federal Funds	-	10,683 2,300[5]	12,400
Benefits:			
Yield Quantity	No change	+ 9.0 to 29.0%	- 25.3 to + 92.2%
Yield Quality	+ 19.0%	No data	No data
Pesticide Use	- 50.0%	No data	- 80.6 to + 177.8%
Production Cost	- 1.5%	No data	- 43.5 to + 47.8%
Profit	+ 3.0 to 15.0%	+ 3.0 to 133.0%	- 18.0 to + 144.0%

1/ Incl. clerical, supplies, equipment, adm. overhead, etc.
2/ Insect pests only
3/ Program objectives included monitoring plant diseases, nematodes, weeds, and soil fertility
4/ Based on total of $40,133 less $2,300 implementation funds = $37,833 : 1,315 acres
5/ Implementation funds

control of the burrowing bug, Pangaeus bilineatus, an insect that first became economically important in this part of Texas in about 1968. Burrowing bugs pierce the peanut hull and feed on kernels, causing yellow to dark spots on the kernel that are termed "pitting" by peanut graders. This damage reduces peanut quality, and penalties are assessed to producers by peanut buyers, based on the percent of kernels damaged. Such penalties for pitted peanuts can range from $3.40 per ton for 2% damaged kernels to $100 per ton for 10% damaged kernels. In 1970, Frio County peanut producers' collective revenue losses due to burrowing bug damage was about $122,000. These losses occurred almost entirely from peanut quality reduction as the burrowing bug does not significantly affect peanut yields.

When the burrowing bug first became a problem, peanut producers in Frio County reacted by heavy insecticide use. Results were unsatisfactory, and problems from secondary pests began to appear. This prompted the Frio County Peanut Improvement Association to seek help from the Texas Agricultural Experiment Station after the 1970 growing season. The pest management program evaluated by Lacewell and Casey was initiated jointly by the peanut growers and the Texas Agricultural Experiment Station and the Texas Agricultural Extension Service in 1971. In 1973, the program covered 6,558 acres on 23 farms and employed 4 scouts. The average workload was 1,640 acres per scout.

Comanche County, Texas Program: This program was initiated in 1973. Its prime objective is control of the lesser cornstalk borer (Elasmopalpus lignosellus), an insect that can reduce peanut yields by 50% or more. Peanut producers' efforts to control this insect in the late 1960's and early 1970's were reaching the point of routine insecticide applications at regular intervals, primarily by aircraft. Intervals between applications were being reduced and quantities of insecticides applied increased, but insect control remained unsatisfactory. The Texas Agricultural Experiment Station and Agricultural Extension Service began working with producers in this area by providing more specific recommendations on appropriate insecticides, application methods, and timing of applications. In 1973, a pilot peanut pest management project was initiated in Comanche County under the auspices of the USDA/State cooperative program. In addition to providing regular insect surveys, program objectives include monitoring plant diseases, nematodes, weeds, and soil fertility.

In 1973, its start-up year, this program included 1,315 acres (about 2% of the total peanut acreage in the county), divided into 42 fields on 33 farms. Three scouts were employed. The average scouting workload was 435 acres per scout.

Oklahoma Program: In Oklahoma, peanuts are an important crop in many counties. Oklahoma peanut producers have experienced a variety of pest problems over the years, including most of the peanut insects, diseases, nematodes and weeds mentioned above (p. 76). An organized pest management program on peanuts was conducted in Oklahoma for the first time in 1973, supported in part by USDA funds. Due to late approval of the State plans, the program had a late and hasty start. It was largely a demonstration porgram, with opportunity to gain experience in operational problems such as obtaining grower support, scout workloads, integration of disciplinary inputs, etc. In 1973, 394 acres on 8 farms, located in 3 different counties, were in the program. One scout team conducted all field survey work.

PROGRAM COSTS

Some cost data are available for each of the 3 peanut pest management programs evaluated in this study. However, since 2 of the 3 programs (Comanche County, Texas, and the Oklahoma program) were initiated only in 1973, the first-year operating costs of these programs probably included substantial non-recurring start-up expenses.

Frio County, Texas: Implementation costs of this program are estimated by Lacewell and Casey at $2,109, (p. E 8-9), consisting of $1,497 for salary and travel expenses of an entomologist surveying the problem, and $612 for scout training. These funds were provided by the Texas Agricultural Extension Service

($1,344) and the Texas Agricultural Experiment Station ($765).

The operating costs of the Frio County program by years, cost elements and source of funds are detailed by Lacewell and Casey (p. E-11, Table E-4). In 1973 (Table 7 , p. 81), these costs totaled $7,882, equivalent to $1.20/acre. Growers contributed $6,558 ($1.00/acre) while the balance, $1,324 was contributed by the Texas Agricultural Extension Service ($865) and the Texas Agricultural Experiment Station ($459).

Comanche County, Texas: In this program, implementation cost elements include mapping, grower contacts, recruiting, scout training, data handling and processing, area delineation, and procedure development. The Texas Agricultural Extension Service contributed $9,950; the Texas Agricultural Experiment Station $5,000, the balance of $2,300 came from USDA cooperative funds.

Total operating costs of this program in 1973 were $40,133, equivalent to $28.77/acre for the 1,315 acres in the program (not including in the total costs $2,300 federal implementation funds). This cost is obviously excessively high on a per-acre basis, even considering the fact that the program was not limited to insect management, but included in its objectives monitoring of plant diseases, nematodes, weeds, and soil fertility. Additional years' experience will be required to determine if program costs can be brought into an economically attractive relationship to program benefits. The program was increased from 1,315 acres in 1973 to 2,800 acres in 1974, with a goal of 7,000 acres for 1975. Participating growers' contributions were increased from $0.25 per acre in 1973 to $1.00/acre in 1974. These are encouraging signs. Participating growers have indicated that in the future, they would be willing to pay all scouting costs up to $3.50 per acre.

Oklahoma: For the Oklahoma program, specific implementation costs are not available. Lacewell and Casey (p. E-48) suggest that implementation costs experienced in Comanche County, Texas ($17,250) may be relevant to the Oklahoma program.

Operating costs for the Oklahoma program by expense items and by sources of funds are detailed by Lacewell and Casey

(p. E-49, Table E-17) and summarized in Table 7 (p. 81). The total operation costs of $41,000 include $20,000 for "field support". This amount was provided by the Hughes County Peanut Growers, for support of the Hughes County demonstration farm. This sum is not included in Table 7 . Assuming that $21,000 were spent to operate the scouting activities of the Oklahoma program, the resulting cost for the 395 acres in the program amounts to $53.16/acre. These costs are, obviously, completely beyond the realm of economic feasibility. It must be remembered that for this program also, 1973 was the start-up year. Program principals in Oklahoma are aware of several opportunities for greater efficiency and economy of the program which will be implemented in subsequent years.

In summary, this report provides implementation cost data for 2 peanut pest management programs (Frio County, Texas, p. E-10) and Comanche County, Texas (p. E-29); 4-year operating cost data for 1 program (Frio County, p. E-11); and first-year operating costs for the remaining 2 programs, i.e., Comanche County (p. E-31) and the Oklahoma program (p. E-49).

Implementation costs were estimated at $2,109 for the Frio County, and at $17,250 for the Comanche County programs.

The operating costs in Frio County (providing insect management only) average about $1.20/acre. First-year costs in the Comanche County program were $28.77/acre, in the Oklahoma program, $53.16/acre. It is emphasized that both of the latter programs were initiated in 1973, the only complete year for which operating cost data are currently available. In addition, both of these programs include not only insect problems, but cover plant diseases, nematodes, weeds, soil fertility, and general plant health problems.

PROGRAM EFFECTIVENESS

The effectiveness of the peanut pest management programs studied was measured by the following criteria:

-- Yield quantity,
-- Yield quality,
-- Pesticide use,
-- Production costs,
-- Profit to growers.

Quantification of these parameters for the programs evaluated is difficult because none of the programs provided in their design for adequate, let alone rigorous economic evaluation.

Effects on yield

Frio County, Texas: As outlined above, this program was initiated by producers for the purpose of obtaining relief from the burrowing bug, an insect that had developed into a key problem, causing substantial peanut quality reductions. In the absence of other pertinent data, Lacewell and Casey (p. E-14) compared the quantities of peanuts damaged by the burrowing bug and the resulting losses in producer revenues for Frio County for 1970, the last year prior to initiation of the pest management program, to the years 1971, 1972, 1973 and 1974 in which the program was in operation. This type of comparison, as the authors point out, does not take into account variations in burrowing bug populations from year to year, nor losses due to other factors such as water shortage, weeds, fertilization, etc., and tends to exaggerate program benefits in light infestation years. In 1970, there were 9,020,000 lbs. of peanuts damaged, costing producers $121,700 in lost revenues. In 1971, these losses were reduced by about 90%. There were only minimal peanut quality losses in 1972, and none in 1973 or 1974.

Lacewell and Casey concluded that in 1973, the program resulted in a 19% increase in peanut quality. There were no effects on the quantities of peanuts harvested as compared to non-participants.

Comanche County, Texas: In this program, there were likewise no "control groups" available for measuring the effectiveness of the pest management program for participating growers. Lacewell and Casey compared the peanut yields of participating producers in 1973 to their own 1971-1972 average yields, and to the County average for 1973. On this basis, the average yield for participating producers, on irrigated as well as on nonirrigated fields, exceeded both their own yields for 1971-1972, and the County average yields for 1973 (p. E-27, Table E-9). Participating growers' yield increases ranged from 9 - 29% (Table 7 , p. 81). Peanut quality was not at issue in the Comanche County program because the key insect in this area, the lesser cornstalk borer, affects yield quantity, but not quality.

Oklahoma program: In this program, yield quantity and quality were recorded for growers participating in the program, separated by irrigated and nonirrigated fields. However, there are no comparable data for non-participating growers. Thus, an assessment of the effects of the program on peanut yields (quantity or quality) of participating growers is not possible.

The 1973 Oklhaoma program also included a field demonstration test in Hughes County, established to evaluate and compare various chemical and cultural practices. Four different management strategies designated as A, B, C, and D were compared. Management level A applied chemical pesticides recommended for the area regardless of need. Management level B-plots received pesticide treatments only when control was needed as indicated by periodic field surveys, with emphasis on minimal pesticide use. Management level C was designed to represent practices considered typical for area peanut producers. Management level D received little or no pesticide applications. Yields and returns per acre from these different management strategies were as follows (from Sturgeon et al., 1974, as discussed by Lacewell and Casey, p. E-47, Table E-16, of this report):

Management strategy	Yield, lbs.per acre	Grade, %	Gross returns, $/A	Total cost, $/A	Net returns $/A
A	4,370	67	684	275	410
B	2,746	68	432	187	245
C	2,274	66	354	186	168
D	1,697	59	243	105	138

Management strategy A incurred the highest production costs, but was clearly superior to the other 3 strategies in regard to yield, and gross and net returns. These results are difficult to interpret because this strategy involved not only higher inputs of chemical pesticides, especially for insect and nematode control, but also use of one additional fertilizer application, and of a growth regulator. The additional fertilizer application as well as the growth regulator application were omitted in plots B, C. and D.

The program benefit data for the Oklahoma program provided by Lacewell and Casey and included in Table 7 are based on comparing the effects of management levels A, B and D to level C.

In summary, the data presented in greater detail by Lacewell and Casey in Appendix E of this report indicate that one of the three peanut pest management programs evaluated (Frio County, Texas) did not change peanut yield quantity, but increased quality by 19% by reducing insect damage. The Comanche County, Texas program increased peanut yield quantity by 9-29%, but did not affect quality. Data available on the Oklahoma program on 8 farms are not adequate for evaluation of program effects on peanut yield quantity or quality. In a demonstration plot, different pest management and cultural strategies affected peanut yield changes from - 25.3 to + 92.2%.

Effects on pesticide use

Pesticide use data available for the 3 peanut pest management programs evaluated are incomplete, but some program effects are evident.

Frio County, Texas: In this program the quantities of preemergence and postemergence insecticides used by participating peanut producers declined from 3.12 lbs. AI/acre in 1971, the first year of the program, to 2.44 lbs. AI/acre in 1972, and to 0.97 lbs. AI/acre in 1973, then re-increased slightly to 1.37 lbs. AI/acre in 1974. There are no comparable data on participating producers' insecticide use practices prior to 1971, nor on the quantities of insecticides used by non-participating producers during the period 1971-1974. Lacewell and Casey point out that burrowing bug infestations in Frio County were heavy in 1971 and 1972, while 1973 and 1974 were light infestation years. Therefore, the marked reduction in the use of insecticides in 1973 and 1974 cannot be entirely attributed to the effects of the pest management program. Nevertheless, Lacewell and Casey believe that the program contributed to reduced (- 50%) and more efficient use of insecticides (p. E-16).

There are no data on the kinds and amounts of pesticides other than insecticides used in Frio County by participating or non-participating peanut producers.

Comanche County, Texas: In this program, quantities of insecticides, herbicides, nematicides, and fungicides used by participating growers were recorded. However, there are no comparable data for non-participating producers. Based on pesticide use patterns in previous seasons, Lacewell and Casey perceive "some indication (that) producers are more effectively using pesticides", but a more definite statement regarding the effects of this program on pesticide use cannot be made (p. E-34).

Oklahoma: In this program, pesticide uses were recorded for the 8 participating growers, but again, no comparable data for non-participating producers are available. In the Hughes County demonstration plots, pesticide inputs varied from -80.6 to

+177.8% of typical local practice. Results indicate that increased pesticide inputs could substantially increase peanut yields. However, as pointed out above, the increased yields and returns in the high pesticide-use plots may have been due, at least in part, to the application of a growth regulator and/or an increased fertilizer rate.

> *In summary, one of the three peanut pest management programs reviewed resulted in decreased pesticide use. There are no adequate data for a meaningful evaluation for the other two programs studied. Field test plot results indicate that in one area in Oklahoma, current pesticide use levels may be suboptimal, and that increased pesticide use would increase peanut yields.*

Effects on production costs

Production costs can be affected in several ways by pest management programs. They could be increased by the cost of the program, decreased by savings in pesticide inputs, or affected in either direction by combinations of these factors.

Complete, detailed production cost records are not available for any of the peanut pest management programs studied, with exception of the demonstration plots in Hughes County, Oklahoma, in 1973 (see p. A-21). In comparison to local conventional practice ("Management Strategy C"), different other management strategies caused changes in total production costs ranging from - 43.5 to +47.8%.

In the Frio County, Texas program, participating producers' production costs decreased slightly (-1.5%) due to decreased insecticide inputs.

No adequate production cost data are available for the Comanche County, Texas program.

Effects on growers' profits

From the peanut producers' standpoint, profit is undoubtedly the most important indicator of the degree of success of pest management programs.

Frio County, Texas: The pest management program resulted in improved peanut quality, decreased use of insecticides, decreased production costs, and a net increase in growers' collective profits estimated by Lacewell and Casey at over $60,000 per year on the average. In years of high burrowing bug infestations, benefits of the program are estimated at $120,000 or more.

Comanche County, Texas: Average peanut yields for a sample of participating growers were compared to a comparable sample of non-participating growers. There were 5 growers using irrigation, and 5 growers not using irrigation in each sample. The average yield per acre for participating producers was 1,917 lbs., worth $268.38. Non-participating growers' yield average was 1,835 lbs. per acre, worth $256.90. Thus, participating producers had an average yield increase of 82 lbs. of peanuts per acre, worth $11.48. Program participants contributed only $0.25/acre toward the cost of this program.

Oklahoma: Data available are not adequate for estimating the effects of the program on the net returns of the 8 growers participating in the team monitoring program. Observations from the demonstration plots in Hughes County indicate highest net returns ($410/acre, see p. E-47) from the highest level of pesticide use. The application of pesticides as needed, based on pest infestation monitoring, produced a net return of only $245/acre. However, as pointed out above, measures other than pesticide inputs may be responsible in whole or in part for the high return experienced at the highest level of pesticide use in this instance.

> *In summary, net profits of peanut growers participating in pest management programs increased in the two programs for which some data are available for evaluation. In one of these programs (Frio County, Texas), growers' increased profits, based on 4-year averages, ranged from 3 to 15% and exceeded the full costs of the pest management program several times. In the other two programs (Comanche County, Texas, and Oklahoma), program costs in 1973, the first year of operation of both programs, were excessively high*

($28.77 and $53.16/acre, respectively, see Table 7), but were largely or entirely paid for from public funds. Net profit changes ranged from + 3 to +133% in the Comanche County, Texas program, and from - 18.0 to + 144% in the Oklahoma demonstration program.

TOBACCO PEST MANAGEMENT PROGRAMS

BACKGROUND

Tobacco is attacked by a number of different pests. Important insect pests of tobacco in the U.S. include the tobacco budworm, Heliothis virescens, and the tobacco hornworm, Manduca sexta. Tobacco budworms inflict damage on tobacco primarily by larval feeding in the terminal vegetative parts of tobacco early in the growing season. Tobacco hornworms, especially the last of the five larval stages of this insect, feed on tobacco leaves; they are capable of completely defoliating tobacco plants.

Plant diseases affecting tobacco include brown spot, Alternaria longipes; black shank, Phytophthora parasitica var. nicotianae; and mosaic, a virus disease. Several species of nematodes and weeds may interfere with production. In addition, chemical plant growth regulators are used extensively on tobacco for "sucker control". Suckers are shoots developing from adventitious buds in leaf axils which, if allowed to grow, would produce foliage and flowers of no commercial value and would thus prevent maximum production of marketable tobacco leaves. Chemical plant growth regulators have been developed to control sucker growth.

An excellent discussion of tobacco pests, of their interactions with plant growth regulators and other production factors, and of scientific approaches to their management has recently been presented by Rabb et al. (1974).

As in the case of peanuts, commercial tobacco growers in the U.S. have practiced pest management to a greater or lesser degree for many years, without specific scientific guidance and before the term as such became known.

TRENDS IN TOBACCO PRODUCTION AND PESTICIDE USE

In 1973, about 890,000 acres of tobacco were grown in the U.S. Average yield per acre was 2,011 lbs. Growers received an average price of $0.897/lb. The total U.S. tobacco production in 1973 was about 1.8 billion lbs., worth about $1.6 billion at the farm level, or about $1,800/acre (U.S. Department of Agriculture 1973b).

The quantities of pesticides (insecticides, fumigants, fungicides, growth regulators) used on tobacco in 1964, 1966 and 1971, according to the USDA surveys for these years, and the U.S. tobacco acreage for the same years are summarized in Table 8. Pesticide use data are available for 1964, 1966, and 1971 for insecticides, fumigants, and growth regulators, and for fungicides only for 1964. No disaggregate data on the use of herbicides on tobacco are included in any of the USDA surveys of the quantities of pesticides used by U.S. farmers.

The total U.S. tobacco acreage ranged from 1,078,000 acres in 1964 to 838,000 acres in 1971. It comprised 892,000 acres in 1973 (U.S. Department of Agriculture, 1974c).

The total quantity of insecticides used on tobacco was about 5 million lbs. of active ingredients (AI) in 1964, and about 4 million lbs. in 1971. On a per-acre basis, use of insecticides on tobacco ranged from a low of 3.9 lbs. in 1966 to 4.8 lbs. in 1971.

The data on the use of fumigants on tobacco included in Table 8 may be misleading because between 1964 and 1971, the USDA changed its procedures. In the earlier years, space and soil fumigants were not separated. In recent years, there has been a trend to greater use of broadcast soil fumigants on tobacco which is not reflected in the USDA data reported in Table 8, probably due to the fact that space fumigants were included in the earlier figures but not in those for 1971 (Good, 1974a).

Because of these problems, fumigants and fungicides have not been included in the totals and averages at the bottom of Table 8, and the data on the use of fumigants on tobacco appear to be of limited usefulness and should not be over-interpreted.

The use of growth regulators on tobacco increased greatly from 1964 to 1971. The total quantity of growth regulators applied to tobacco doubled during this period, from 2.5 million lbs. AI in 1964 to almost 5 million lbs. in 1971. On an area basis, plant

Table 8: U.S. Tobacco Acreage and Use of Pesticides on Tobacco, 1964 - 1971

Year	1964	1966	1971
Tobacco Acreage[1/] (1,000 Acres)	1,078	972	838
Pesticide Use on Tobacco:			
Insecticides[2/]			
- Total (1,000 lbs. AI)	4,997	3,791	3,999
- per Acre (lbs. AI)	4.6	3.9	4.8
Fumigants			
- Total (1,000 lbs. AI)	15,066	10,334	4,429
- per Acre (lbs. AI)	14.0	10.6	5.3
Growth Regulators			
- Total (1,000 lbs. AI)	2,484	3,058	4,978
- per Acre (lbs. AI)	2.3	3.2	5.9
Fungicides			
- Total (1,000 lbs. AI)	2,359	N.a.	N.a.
- per Acre (lbs. AI)	2.2	N.a.	N.a.
Herbicides	N.a.	N.a.	N.a.
Total, Insecticides and Growth Reg.'s			
- Total (1,000 lbs. AI)	7,481	6,849	8,977
- per Acre (lbs. AI)	6.9	7.0	10.7

1/ All types of tobacco

2/ Excl. petroleum

Source: U.S. Department of Agriculture (1968c, 1968b, 1970, 1973a, 1973b, 1974a) growth regulator use increased by more than 150%, from 2.3 lbs. AI/acre in 1964 to 5.9 lbs./acre in 1971.

The combined volume of tobacco insecticides and growth regulators increased from about 7.5 million lbs. AI in 1964 to 9.0 million lbs. in 1971. This increase is due primarily to the increased use of growth regulators. On an area basis, the use of insecticides and growth regulators combined amounted to 6.9, 7.0 and 10.7 lbs. AI/acre in 1964, 1966 and 1971, respectively.

USERS, LOCATIONS AND CHARACTERISTICS OF THE PROGRAMS STUDIED

Figure 3 presents an overview of the geographical distribution of the U.S. tobacco acreage in 1969 by way of a dot-map (1969 is the latest year for which such dot-maps are available). The total U.S. tobacco acreage in 1969 was 877,000 acres, relatively close to the 892,000 acres grown in 1973. Tobacco production statistics indicate that the geographical distribution of tobacco in the U.S. per Figure 3 is still representative for 1973.

North Carolina is the leading tobacco-producing state in the U.S. with about 375,000 acres, that is more than 40% of the U.S. total.

North Carolina appears to be the only state in which an organized tobacco pest management program meeting the criteria set forth in the introduction to this report is currently in operation. The locations of North Carolina's 3 major tobacco pest management programs are indicated by circles in Figure 3 .

North Carolina's tobacco pest management program was one of the two "pilot pest management projects" initiated in 1971 with support from the USDA/State cooperative program.

Table 9 summarizes the characteristics, costs and benefits of the North Carolina tobacco pest management program for the three years for which data are available, 1971-1973, based on Carlson and Cooper's more detailed description and analysis in Appendix F of this report.

In 1971 and 1972, the program was operated in 5 counties, expanding to 10 counties in 1973. It included:

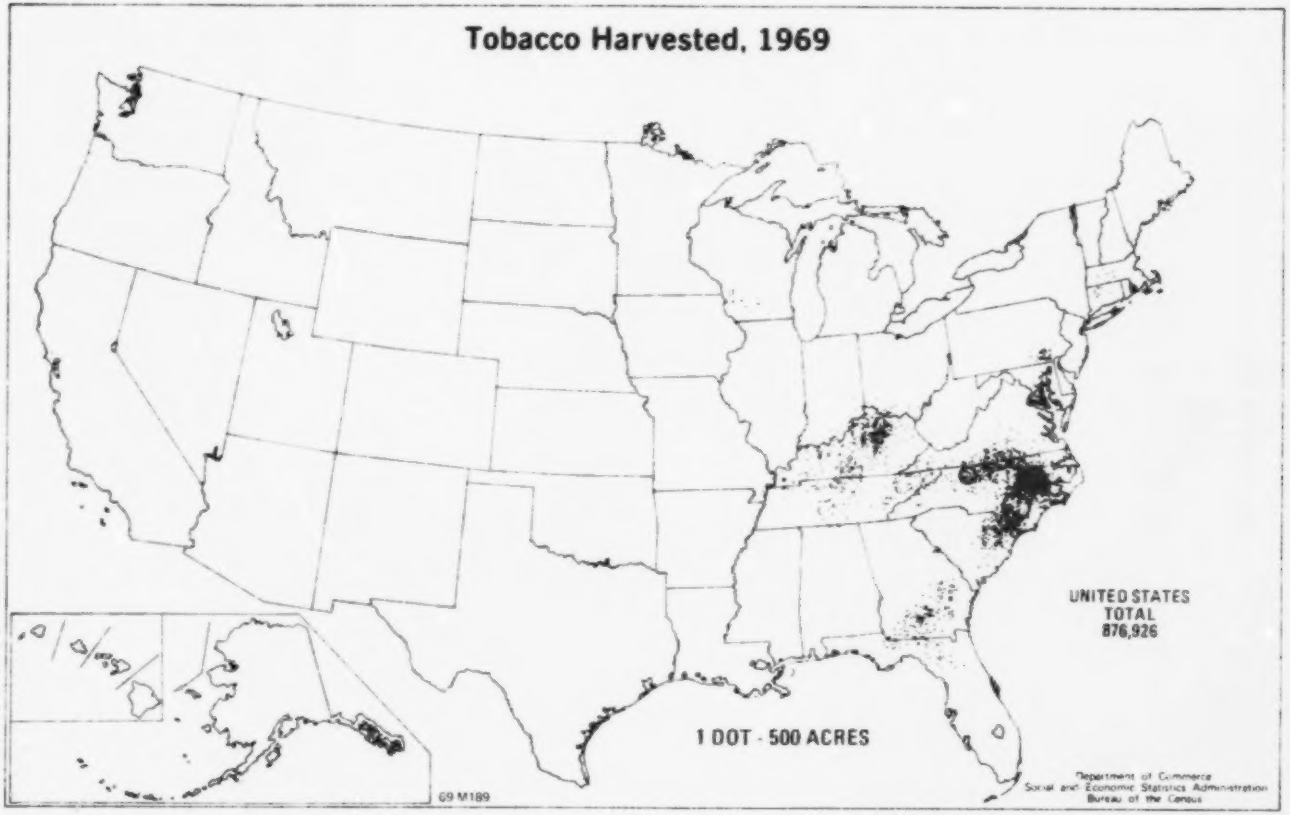
Tobacco Harvested, 1969
UNITED STATES
TOTAL
876,926
1 DOT - 500 ACRES
Department of Commerce
Social and Economic Statistics Administration
Bureau of the Census
69 M189

Figure 3 : Locations of the Tobacco Pest Management Programs Evaluated in this Report Relative to the Geographic Distribution of Tobacco Acreage in the U.S. (Program locations indicated by circles).

Table 9: Characteristics, Costs and Benefits of the North Carolina Tobacco Pest Management Programs, 1971 - 1973

Program Location	3 areas in North Carolina		
Objective	Insect pest suppression		
Year started	1971		
Year	1971	1972	1973
Area	5 Counties	5 Counties	10 Counties
Acres) in IPM	8,032	8,498	11,350
Farms) in IPM	1,531	1,680	813
Fields) in IPM	3,076	3,339	3,448
# Scouts	37	39	33
Farms/Scout	41.2	43.1	24.6
Fields/Scout	83.1	85.6	104.5
Acres/Scout	217.1	217.9	343.9
Sites/Field	5	5	4
Insect Management Costs, $	per Acre	per Acre	per Acre
Scouts	5.49	5.33	3.94
Scout Travel	1.03	0.81	0.76
Scout Supv.	N.a.	1.47	1.38
Co. Agents	N.a.	1.32	1.32
Prof. Support	N.a.	3.75	3.44
Other[1]	N.a.	5.12	6.29
Subtotal	14.91	17.80	17.13
Insecticides	3.25	2.12	2.18
Application	5.52	3.61	4.37
Total	23.68	23.53	23.68
Source of Funds:			
Scouting Program	Public funds	Public funds	Public funds
Insecticides& Appl.	Grower funds	Grower funds	Grower funds
Benefits:			
Yield	No change	No change	No change
Insecticide Use	- 22.5%	- 43.5%	- 29.0%
Production Costs	- $2.51/acre[2]	- $5.55/acre[2]	- $4.73/acre[2]
Profit	+ $2.51/acre[2]	+ $5.55/acre[2]	+ $4.73/acre[2]

1/ Incl. clerical, data processing, env. monitoring, ongoing research, regulatory personnel, supplies, insect identification, and Exp. Sta. & Extension administration.

2/ Due to reduced use of insecticides, disregarding scouting costs.
Program participants did not contribute to the scouting costs which, if they had to be borne by growers entirely, would more than offset the savings in costs of insecticides and their application.

8,032 acres in 3,076 fields and 1,531 farms in 1971
8,498 acres in 3,339 fields and 1,680 farms in 1972
11,350 acres in 3,448 fields and 813 farms in 1973

Thirty-seven scouts were employed in 1971, 39 in 1972, and 33 in 1973.

When the program was expanded to 5 additional counties and to a total of 11,350 acres in 1973, the number of fields increased only slightly to 3,448, and the number of participating farms decreased by about 50%. Thus, there were considerably more acres per field and per farm in the program in 1973 as compared to the first two years. At the same time, the number of sites sampled per field was reduced from 5 in 1971 and 1972 to 4 in 1973. These changes resulted in considerable improvements in scouting efficiency in 1973. Only 33 scouts were employed in 1973.

PROGRAM COSTS

Public and farm costs of the North Carolina tobacco pest management program were analyzed in detail by Carlson and Cooper (p. F-22 to F-39). These costs are summarized on a per-acre basis in Table 9 . No breakdown of implementation vs. ongoing operating costs is available for this program.

Scouting costs per acre (including scout salaries and travel) decreased from $6.52 in 1971 to $6.14 in 1972, and to $4.70 in 1973, even though scout wage rates rose from $2.48/hour in 1971 to $2.76 per hour in 1973. Changes in the work accomplished per hour were thought to have caused this reduction in scouting costs. A detailed mathematical analysis of all scouting cost elements by Carlson and Cooper indicates that the size of program farm is related to travel expenses; on large farms, scouts have to drive greater distances to cover all fields. It is further believed that significant decreases in total scouting costs were obtained by paying scouts by a "piece rate" incentive scheme, instead of by the hour. Additional program cost savings in 1973 as compared to the preceding years were realized by reducing the number of sites per field from 5 to 4, and by counting pests only when the crop was at the most susceptible stage of growth. These program changes all contributed to reducing the time spent per field.

While the per-acre cost for scouting decreased substantially from 1972 to 1973 (Table 9 , p. 98 ; Table 3.5 p. F-28), program costs for clerical and data processing services, and for ongoing research, regulatory personnel, supplies, insect collection and identification, and experiment station and extension administration increased from 1972 to 1973, offsetting most of the savings in the scouting costs. Thus, total program costs decreased by only $0.67 per acre from 1972 to 1973. If participating growers' costs for insecticides and application are added to the program costs, total insect management costs for program participants varied very little between the 3 program years.

> *For each of the 3 program years, scouting costs alone were higher than the savings in costs of insecticides and application realized by program participants, as discussed in greater detail below, p. 102-103.*

PROGRAM EFFECTIVENESS

From 1971 - 1973, the North Carolina tobacco pest management program focused primarily on the 2 major foliar insect pests of tobacco, the tobacco hornworm and the tobacco budworm. In fact, it called itself an insect pest management program (Ellis, 1974). Program objectives included maximum natural suppression of budworms and hornworms by beneficial species; application of selective insecticides only as needed, as determined by weekly scouting; effective sucker control as an aid to suppressing the hornworm; and early stalk destruction to suppress overwintering pests and diseases. These objectives were designed primarily to reduce unnecessary insecticide use and, thereby, save growers production costs and increase their profits without loss in tobacco yield or quality (Carlson and Cooper, p. F-2).

The effectiveness of the North Carolina tobacco pest management program was measured by several criteria, including yield quantity and quality, pesticide use, production costs, and profit to growers. In addition to these parameters, Carlson and Cooper provide data on the abundance of pest and beneficial insects by years and pest management program areas (p. F-9, Table 2.3), and on timeliness of stalk destruction (p. F-19, 20). These authors rejected the degree of pest management acceptance as measured by percent of acreage scouted in a county as a useful benefit indicator, pointing out that acceptance due to program benefits is difficult to distinguish from acceptance due to project "salesmanship".

As with most other pest management programs studied, the design of the North Carolina tobacco program did not include provision for measuring program effects in comparison to suitable non-program "control groups".

Effects on yield

The program did not include yield quantity or quality improvement among its objectives. Carlson and Cooper made a comprehensive study, involving 4 counties in the program, in an attempt to isolate possible program-related effects on tobacco yields (p. F-14 ff.). Random samples of 50 farms in the program and 50 farms not in the program were taken from County Agricultural Stabilization and Conservation Service (ASCS) records in Wilson, Columbus, Bladen, and Cumberland Counties for the years 1969 through 1973. Four types of yield differences were tested for each county, i.e., (1) years before the program for non-program farms compared to program farms; (2) years during the program for non-program farms compared to program farms; (3) non-program farms, years before the program compared to years during the program; and (4) program farms, years before the program compared to years during the program.

In a further effort to identify any program effects on tobacco yields, another set of tests was made involving Wilson, Bladen and Columbus Counties. For each county, yields for the years before the program were compared to yields for each year during the program for program and non-program farms.

> *The results of the two tests were in good agreement with one another, indicating that the North Carolina tobacco pest management program had no significant positive (or negative) effects on tobacco yields.*

Effects on pesticide use

Carlson and Cooper (p. F-31 ff., Table 3.8) report the number of insecticide applications, and pounds of insecticides applied per acre per year for participating farms by counties for 1971, 1972, and 1973. In each of the 3 years, the program means were substantially below the USDA estimates for all North Carolina tobacco farms in 1971. For instance, unpublished 1971 USDA survey data indicate that the average use of insecticides in Surry County was 2.03 lbs. per acre, that is 4.6 times the quantity used in the same county in 1971 by program participants. As summarized in Table 9, Carlson and Cooper concluded that the program reduced insecticide inputs by 22.5% in 1971, 43.5% in 1972, and 29.0% in 1973 (3 year average = - 31.7%).

Quantities of other pesticides (fumigants, fungicides, herbicides, growth regulators) used on tobacco were apparently not studied or recorded in the North Carolina tobacco pest management program and consequently, no information is available on the effects (if any) of the program on inputs of pesticides other than insecticides.

In summary, the program resulted in a decrease in the use of insecticides in each of the 3 program years for which data are available at this time. Reductions in insecticide inputs ranged from 22.5 to43.5%; the 3-year average reduction was 31.7%.

Effects on production costs

Detailed production cost records are not available for the North Carolina tobacco pest management program. According to Carlson and Cooper (p. F-27 ff., Table 3.6), the estimated cost of insecticides plus application for all tobacco farms in North Carolina was $11.28/acre in 1971. The same cost for pest management program farms in 1971 was estimated at $8.77/acre, indicating a cost saving of $2.51/acre for program farms. If the insect control costs for non-program growers were the same in 1972 and 1973 as in 1971, cost savings for program participants would have been $5.55/acre in 1972 and $4.73 per acre in 1973. However, participating growers did not contribute any funds to the cost of the pest management program.

In each of the 3 program years, the cost of scouting (scout salaries and travel expenses) alone exceeded the monetary value of the insecticide and application costs saved, even though significant increases in scouting efficiency and decreases in scouting costs were achieved in 1973, as outlined above (p. 99 and Table 9, p. 98), and in greater detail by Carlson and Cooper (p. F-22 ff., Tables F-3.4, 3.5). If growers had had to bear the entire cost of the pest management program, their production costs would have increased substantially in comparison to non-program growers.

Effects on growers' profits

Tobacco growers participating in the North Carolina pest management program experienced, on the average, a small profit increase due to savings in insecticides and application, ranging from $2.51 to $5.55/acre (3-year average = $4.26/acre). However, as pointed out above, they did not contribute to the scouting costs. Scouting costs alone, disregarding other program cost elements, more than offset the savings in costs of insecticides and application.

Thus, one has to conclude that it probably would be difficult to promote this program on a voluntary basis. To save about $4 - 5/acre, partially or totally offset by program costs, would not be attractive for tobacco growers. In addition, county agents would be reluctant to spend time on a program that has no yield or quality improvement objectives.

Effects on tobacco sucker control and stalk destruction

Promotion of effective sucker control through properly timed application of chemical growth regulators was included among the prime objectives of North Carolina tobacco pest management program. Program effects on stalk destruction are discussed by Carlson and Cooper (p. F-19, 20). Early stalk destruction reduces overwintering populations of tobacco hornworms and budworms by eliminating the food sources for these insect pests when they are entering diapause. The degree of properly timed stalk destruction during 1971-1973 left much to be desired, but the program appears to have contributed significant improvements. For instance, in Wayne and Wilson Counties, approximately 98% of harvested tobacco fields contained undestroyed stalks by the end of August in 1971. In 1972, only about 35% of the fields contained undestroyed stalks at the same time, but in 1973, the percentage of fields with undestroyed stalks went back up to 55%. In Columbus and Bladen Counties, there was significant improvement in stalk reduction between 1971 and 1972, but no further improvement from 1972 to 1973.

The requirements for the timing of stalk removal vary, depending upon the pest or disease that is to be suppressed. However, quantitative data on the effects of stalk destruction, and thus evidence with which to convince growers, appears to be lacking (p. F-20).

In summary, the program appears to have resulted in some improvements in stalk destruction timing.

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Appendix A-i

EVALUATION OF
PEST MANAGEMENT PROGRAMS FOR COTTON
IN MISSISSIPPI, ALABAMA AND LOUISIANA

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Draft Report September, 1974
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A1a

TABLE OF CONTENTS

Page

Introduction A-1

Characterization of Cotton Insect Pests A-2
    Key Pests A-2
    Occasional Pests A-2
    Secondary Pests A-4

Relationship of Insect Pests to Cotton Crop Development A-5
    Pre-season Planning A-8
    Planting Activities A-10
    Seedling Stage A-10
    Early-Season A-10
    Mid-Season A-14
    Late Season A-14
    Fall Program A-14

Cotton Insect Control Program A-17
    Preventative (scheduled) Insecticide Applications A-17
        1. Adverse effects on nontarget organisms A-18
        2. Development of new pests and resurgence of treated population A-18
        3. Development of insecticide resistant populations . . A-18
    Prescription (Scouting) Insecticide Program A-19
    Pest Management (Integrated Program) A-20

Possible Alternatives Faced in Cotton Insect Management A-22
    Effective Non-Persistent Insecticides A-23
    Effective Pesticides Which are Restricted or Prohibited . . . A-23
    Ineffective Insecticides Because of Insecticide Resistance A-23

Specific Programs A-25
    Mississippi A-25
        I. Mississippi, 1972; Specific Program:
            Grenada-Yalobusha Pest Management Society, Inc.. A-26
                Characteristics A-26
                Users and Location A-26
                Biological Effectiveness A-27
                Types and Amounts of Costs A-28
                Environmental Impact A-28
                Overall Feasibility A-28
            Statewide Program, 1972 . . . . A-30

TABLE OF CONTENTS (CONTINUED)

Page

II. Mississippi, 1973; Specific Program:
Grenada-Yalobusha Pest Management Society, Inc. . . A-31
Characteristics A-31
Users and Location A-31
Biological Effectiveness A-32
Types and Amounts of Costs A-32
Environmental Impact A-32
Overall Feasibility A-32
Statewide Program, 1973 . . . . A-34

Alabama A-36
I. Alabama, 1972; Specific Program: 1972 Alabama
Cotton Pest Management Program A-36
Characteristics A-36
Users and Location A-37
Biological Effectiveness A-38
Types and Amounts of Costs A-39
Environmental Impact A-39
Overall Feasibility A-40

II. Alabama, 1973; Specific Program: 1973 Alabama
Cotton Pest Management Program A-41
Characteristics A-41
Users and Location A-42
Biological Effectiveness A-43
Types and Amounts of Costs A-43
Environmental Impact A-43
Overall Feasibility A-44

Louisiana A-46
I. Louisiana, 1972; Specific Program: Louisiana
Cotton Pest Management Program A-47
Characteristics A-47
Users and Location A-48
Biological Effectiveness A-48
Types and Amounts of Costs A-48
Environmental Impact A-48
Overall Feasibility A-49

Insecticide Material and Application Costs A-51

Summary A-59

References A-61

TABLE OF CONTENTS (CONCLUDED)

Page

List of Tables

Table A1. Approximate cotton production costs per acre, 6-row equipment, solid planted, and usual farm practice, Midsouth, 1972 . . . . A-52

Table A2. Calendar insecticide program and representation insecticide program for Mississippi and Alabama pilot areas, 1972 and 1973 . . . . . . A-55

List of Figures

Figure A1. Chart of development of cotton indicating stages, events, pests and activities during the season A-6

Figure A2. Thrips infestation period of importance indicated on the chart of cotton development . A-11

Figure A3. Tarnished plant bug and fleahopper potential infestation period indicated on the chart of cotton development A-12

Figure A4. Boll weevil infestation indicated on the chart of cotton development, illustrating three generations usually occurring on cotton in the Midsouth A-13

Figure A5. Heliothis spp., bollworm and tobacco budworm, infestations (three peaks) during the growing season shown on the chart of cotton development A-15

Note: Use of trade names in this report is for identification only and does not constitute endorsement of these products or imply discrimination against other similar products.

INTRODUCTION

Cotton insect control is in a period of transition from almost total reliance on chemical pesticides to a program of integrated pest management. The causes of this transition are: pesticide residues and subsequent regulations, development of insecticide resistance in target and some previously non-target pests, high cost of unnecessary insecticide and development of a cadre of competent entomology consultants. These entomology consultants are licensed by the state after meeting certain educational requirements and are required to maintain in-service training. They are skilled professionals contracted by farmers for a per acre fee to advise a season long cotton insect control program. They are the key people who will have the skill to implement future integrated cotton insect management programs.

This section of this report is an overview of cotton insect management strategies. It includes a characterization of cotton insect pests, the relationships of insect pests to cotton crop development, cotton insect control programs - past, present, future, and some possible alternatives faced in cotton insect management and control in the future.[1]

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[1] The author is indebted to F. A. Harris, Mississippi State University Entomology Department, for assistance in development of this section of the report.

CHARACTERIZATION OF COTTON INSECT PESTS:

Key Pests

Boll weevil.--The key pest of cotton in the Midsouth is the boll weevil (16), a perennially occurring and persistent pest that dominates control practices. This point is argued by some farmers and entomologists in certain areas of Mississippi, especially the Delta area where boll weevils survive in relatively low numbers. From the "current situation only" point of view the secondary bollworm complex appears to be the key problem. A historical point of view and an understanding of the ecological upsets caused by pesticides, however, leads one to realize that the boll weevil was the pest that started the "pesticide syndrome" (11) in cotton in the Midsouth. Thus it is greatly responsible for release of secondary pests and other pesticide related problems. The boll weevil must be controlled by ecologically sound methods if the pest management concept is to be practically applied to cotton in the Midsouth.

Occasional Pests

Plant Bugs and Fleahoppers.--The tarnished plant bug, *Lygus lineolaris* (Palisot de Beauvois), and the cotton fleahopper, *Pseudatomoscelis seriatus* (Reuter), are occasional pests that create problems in some areas of the Midsouth in some years. The relative importance of these two bugs is not known. Their pest status is also unknown where in-season pesticides for boll weevil control are eliminated over a wide area for a sustained period of time. The known potential of the plant bugs to cause serious crop damage makes them important to pest management research. These pests might be elevated to key pest status in a system where they are not being controlled by insecticides applied for boll weevil and bollworm control.

Thrips.--Thrips can be categorized as occasional pests of cotton in the Midsouth and their significance to pest management schemes for other cotton pests is not known. The widespread use of systemic insecticides for thrips control on seedling cotton might decimate natural enemies beyond the point of recovery, especially in the intensively cultivated Delta area. On the other hand, insect samples from a small plot systemic insecticide test in 1972 showed higher populations of natural enemies in the treated plots 6 to 8 weeks after treatment than in untreated plots (Unpublished data of F. A. Harris, MSU Entomology Department). This may have been preference for the larger more densely foliated plants in the treated plots, but greater biomass in the treated plots may have increased reproductive potential of the natural enemies. Cotton plants often recover from thrips injury with no measurable effect later in the season, but severe thrips injury can reduce stand, retard plant growth, delay crop maturity and reduce yield (19). Thus thrips control practices interact with agronomic, disease control, weed control and harvest practices. Thrips may need more attention than is currently being given to them in our pest management research efforts.

Other Occasional Pests.--Several other pests of cotton are characterized as occasional because they occur periodically, are not particularly related to control of any other pest, and they require insecticide treatments for control. These are cutworms, aphids (rare), cabbage looper, and armyworms (especially beet armyworms). Since these pests are minor and occasional, little research attention is given to them.

Secondary Pests

Several important secondary pests occur on cotton in the Midsouth. These are insects that have been elevated to pest status or that have become more significant because of pesticides applied for key or occasional pests.

Bandedwing Whitefly.--Populations of the bandedwing whitefly, *Trialeurodes abutilonea* (Haldeman), on cotton are increasing in Mississippi because of pesticide resistance and destruction of their natural enemies. Severe problems, such as have occurred in neighboring Louisiana, have not yet been experienced, but the whitefly is under careful observation because of its potential as a damaging pest. Spider mites, primarily the twospotted spider mite, *Tetranychus urticae* (Koch), is a locally serious secondary pest of cotton. The bollworm, *Heliothis zea* (Boddie) and tobacco budworm, *H. virescens* (F.), are the most important secondary pests of cotton in Mississippi. The larvae of both these insects are difficult to control, especially the mid and late instars, even when the populations are susceptible to the insecticides being used. Increasing resistance in these Heliothis species, especially the tobacco budworm (15), has frequently made economic control very difficult, and in a few alarming cases in Mississippi control has not been achieved with high rates of both organochlorine and organophosphate insecticides. During two recent years, 1969 and 1972, high density tobacco budworm infestations have occurred late in the season on cotton. These infestations reached damaging levels late in August and continued at high densities until mid-September in both years. The crop was relatively late in 1969. Under those circumstances tobacco budworm control was both expensive and relatively ineffective. Part of the 1972 crop was unusually early, having matured a majority of the bolls in most fields by early September. These mature fields of cotton generally escaped serious injury from the late season tobacco budworm infestation in 1972. However, scattered around the Mississippi Delta were numerous fields of late maturing cotton, delayed by a late planting date, excessive herbicide treatment or other reasons. On some of these late fields of cotton in September of 1972 tobacco budworm larvae ruined the crop even though heavy rates of Methyl Parathion and/or Toxaphene-DDT were being applied on a 2-3 day schedule (Harris, personal observations). This problem is unquestionably increasing in Mississippi.

RELATIONSHIP OF INSECT PESTS TO COTTON CROP DEVELOPMENT:

A chart of certain aspects of the seasonal development of cotton is shown in Figure A1. This chart shows some of the stages of development, or events that occur, as a cotton crop progresses through the

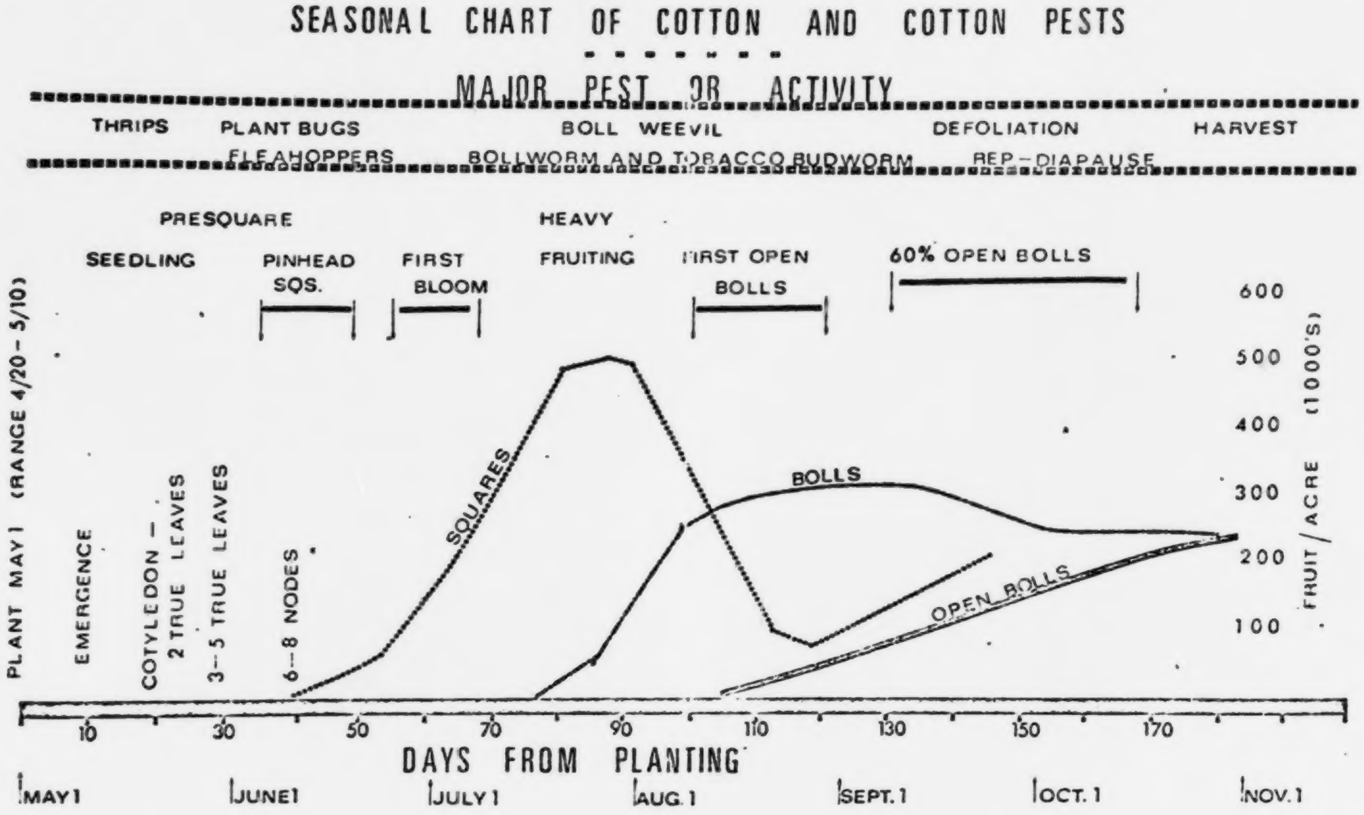

Figure A 1.-Chart of development of cotton indicating stages, events, pests and activities during the season.
Source: (18)

growing season. Also indicated are the major pests or insect pest management activities for various periods during the season. The timing of events in the development of cotton is highly variable and depends on many factors such as weather, soil fertility, variety, seed quality, land preparation, weed control and others.

The chart illustrates a crop planted on May 1. However, planting dates may be as early as April 10 and under adverse conditions extend into late May. The seedlings usually emerge in 5 to 8 days but emergence may occur from 4 to 14 days after planting being primarily determined by soil temperature. The seedling stage, cotyledon to 2 true leaves, will last about 10 days followed by the presquare stage, also about 10 days in length. In early June the first squares will appear. This stage is called the pinhead square stage because the fruit on the plants are the very young and tiny flower buds or squares. In 20 to 25 days after the first squares appear, the crop will begin blooming. When the first blooms appear the crop is normally in a state of highly accelerated rate of fruiting which reaches a peak in late July and early August.

This period of accelerated fruiting rate in July and August is extremely important. The crop usually will have the best growing conditions during this period with the fewest external and internal stresses. Bolls set during this period mature faster and produce higher quality lint and seed then those set at other times.

The crop begins to load up with bolls in August. These bolls have high demands for carbohydrate produced by the plants' process of photosynthesis. Thus a kind of internal stress is created in the plants. At this stage, external stresses, such as prolonged cloud cover or drought, cause shedding of squares, blooms and young bolls. These shedding events are important in insect pest management, because when insects are feeding on fruit that will shed, they cause no economic damage. Thus the crop will tolerate higher infestations. However, extensive shedding, leaving predominantly harvestable bolls on the crop, can be disastrous if a heavy insect infestation occurs at the same time and is forced to feed on the bolls.

As the crop matures in late August and September the bolls begin opening and a decision to defoliate is based on 60% open bolls, usually between mid-September and mid-October. Of course, defoliation is soon followed by harvest and finally the crop residue may be destroyed and turned under by disking or other fall land preparation.

Insect pest management in cotton extends from pre-season planning through the season and ends with a fall program of controlling diapausing boll weevils. The following discussion is a relation of current insect problems and control approaches to the seasonal development of the cotton crop.

Pre-season Planning.--Several decisions must be made prior to the beginning of the crop growing season. The cotton variety must be chosen. At the present time commercial cotton varieties are not rated upon tolerance or resistance to insect damage. However, in the future insect resistant varieties probably will be available and their use will have to be considered in insect pest management decisions.

Several options for thrips control must be considered. Seed treatments, in-furrow granules or foliar sprays are recommended. The systemic insecticide seed treatment or in-furrow granules should be used only on high quality seed and in areas where thrips are a perennial problem. If foliar sprays are decided upon, scouting for thrips infestations should begin immediately after cotton emerges to a stand.

Decisions about cotton seed are important pre-season planning activities. High seed quality is essential if systemic insecticides are to be used as seed treatments or in-furrow granules. In all cases, high quality seed protected from seedling diseases by a seed protectant and systemic fungicide is a good investment in insect pest management. A healthy, vigorous stand of cotton is less likely to suffer delay and yield reduction from thrips, plant bugs, fleahoppers and organophosphorus insecticides than a skimpy, unhealthy stand.

The decision on thrips control may dictate the use of special equipment such as granular applicators or a sprayer, or on the other hand the equipment available may dictate the method of thrips control chosen.

Finally, in pre-season planning the use of boll weevil traps (Leggett traps)should be given some thought. Traps and grandlure (sex and aggregating pheromone) may soon be registered and commercially available. These traps can be an important detection tool for boll weevil hot spots and an indicator of peak emergence of boll weevils from hibernation. Hopefully, the boll weevil pheromone will soon be developed to the stage of being recommended for practical application in boll weevil control.

Planting Activities.--The planting activities related to insect pest management include all those practices related to obtaining a healthy vigorous stand of cotton, such as seed bed preparation, seeding rate, depth of planting and seedling disease control. Of course, in-furrow granular application of systemic insecticides for thrips control must be applied at planting time.

Seedling Stage.--Thrips are the predominant pest during the 10-12 day seedling stage (Figure 2). Occasionally thrips will damage cotton for a longer period of time but this is not common. Aphids and cutworms are occasional pests on seedling cotton and must be controlled in infested spots.

Early-Season.--The early season stage, i.e., presquare to pinhead square to pre-bloom stage, is a critical decision period for insect pest management. Plant bugs and fleahoppers moving into cotton during this stage (Figure 3) can delay crop maturity and reduce yield. Insecticidal control late in this stage increases chances of increasing bollworm and tobacco budworm problems because their natural enemies are destroyed. Boll weevils, emerged from hibernation, begin laying eggs in young squares during this period (Figure 4). For several reasons, fruiting rate and pest and beneficial insect infestation rates, the stage is being set for the remainder of the season. Control decisions must be carefully weighed.

Spider mites occasionally develop spotted infestations during early season and subsequent stages of the crop. The spider mite infested spots should be treated with a recommended miticide. General spray applications for spot infestations should be avoided.

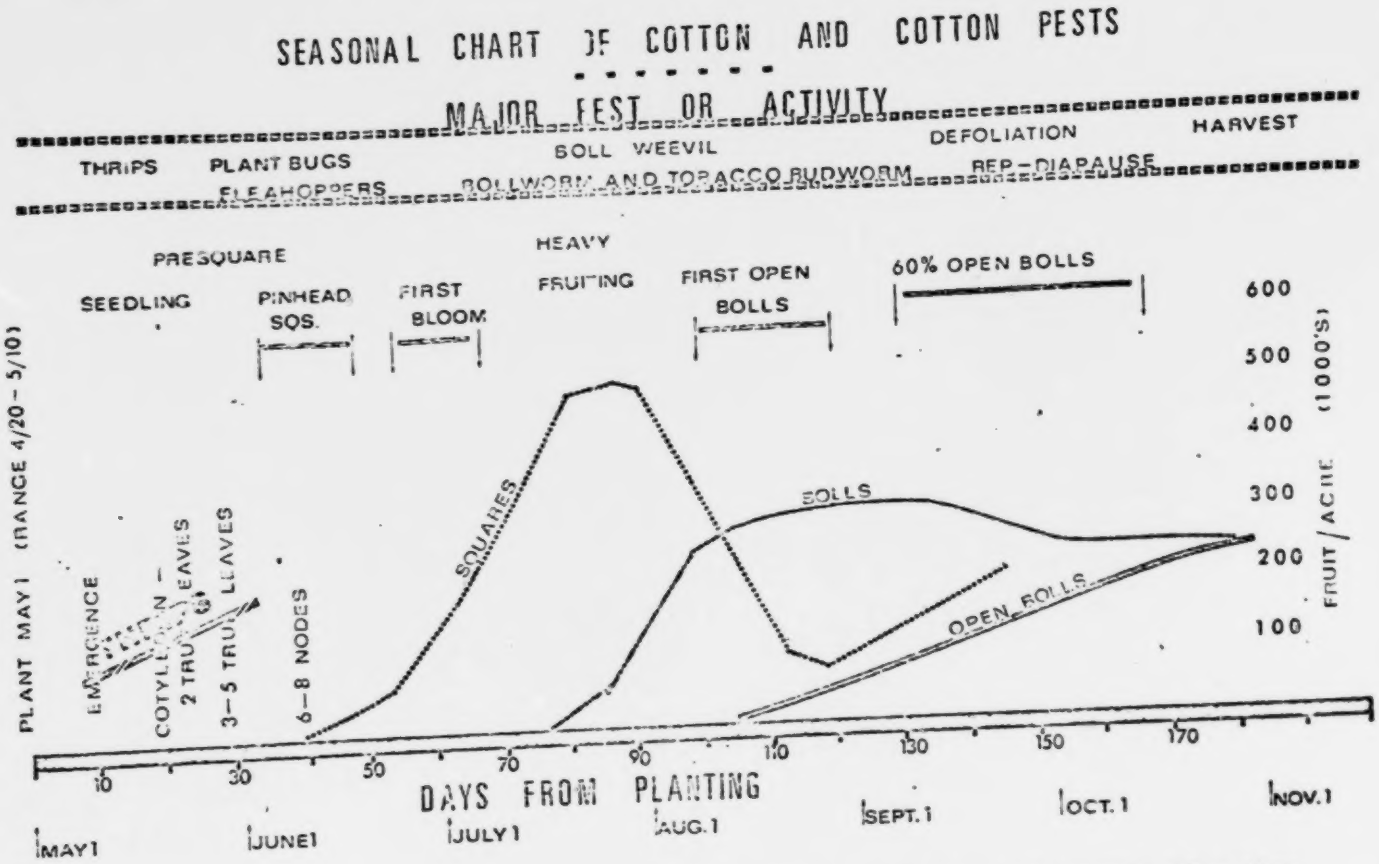

Figure A2.-Thrips infestation period of importance indicated on the chart of cotton development.

Source: (18)

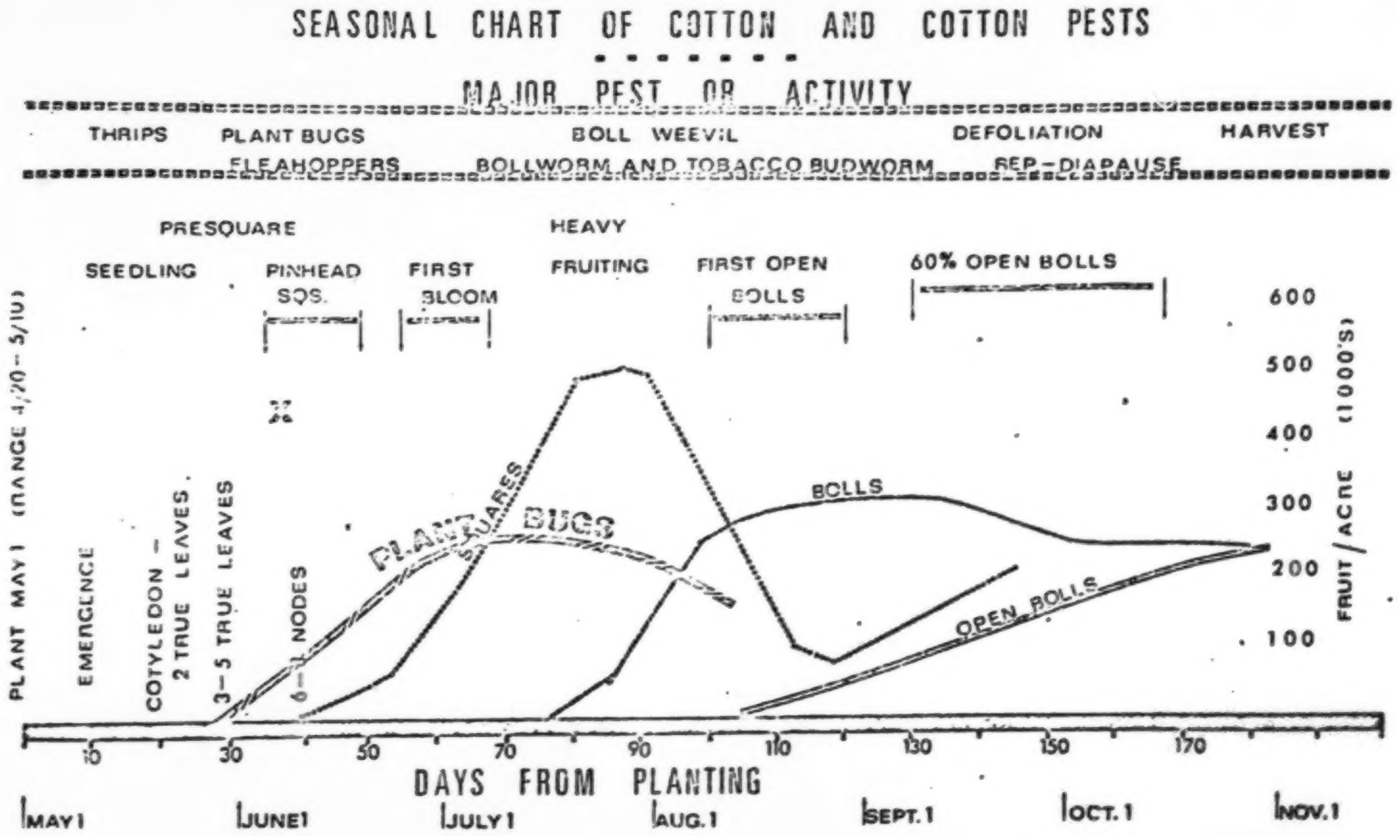

Figure A3.-Tarnished plant bug and fleahopper potential infestation period indicated on the chart of cotton development.

Source: (18)

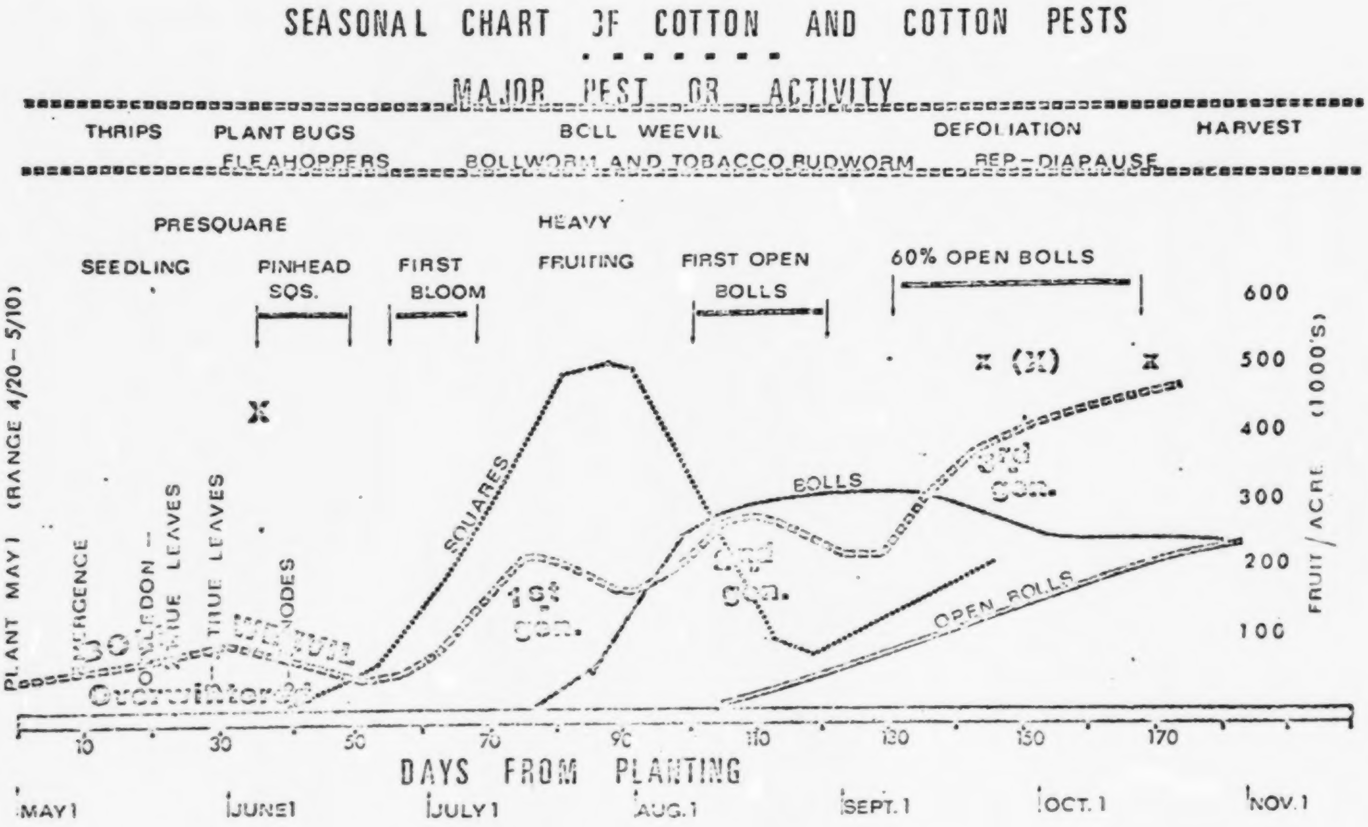

Figure A4.-Boll weevil infestation indicated on the chart of cotton development, illustrating three generations usually occurring on cotton in the Midsouth.
Source: (18)

Mid-Season.--The period from first bloom through heavy fruiting is the critical time for setting the bolls that will be matured out during the late season. Although losses to insects during the mid-season stage must be avoided, this period is least likely to need insecticide applications under good insect pest management practices. If plant bugs, fleahoppers and overwintered boll weevils must be controlled in early season, it should be done early enough to allow recovery of natural enemies for suppression of bollworms and tobacco budworms during mid-season (early-season decision period for insecticide use is marked by the 'X' on Figure 3). Reproduction-diapause control of boll weevils the previous fall should alleviate economic infestations of boll weevil during mid-season. In most cases where good insect management has been practiced, bollworm and tobacco budworm (Figure 5) control in mid-season can be delayed until a combination of eggs, small larvae and 5% square damage is found. Boll weevil control should be initiated when 10% punctured squares are found.

Late Season.--The late season period from first open bolls to 60% open bolls usually occurs from late August through mid-to-late September. Boll weevil or bollworm - tobacco budworm infestations or both reach their highest peaks during this period and control with insecticides is usually required. In addition whiteflies are becoming a more generally distributed and more serious pest because of resistance to insecticides.

Fall Program.--The reproduction-diapause boll weevil control program is designed to kill diapausing boll weevils in the fall before

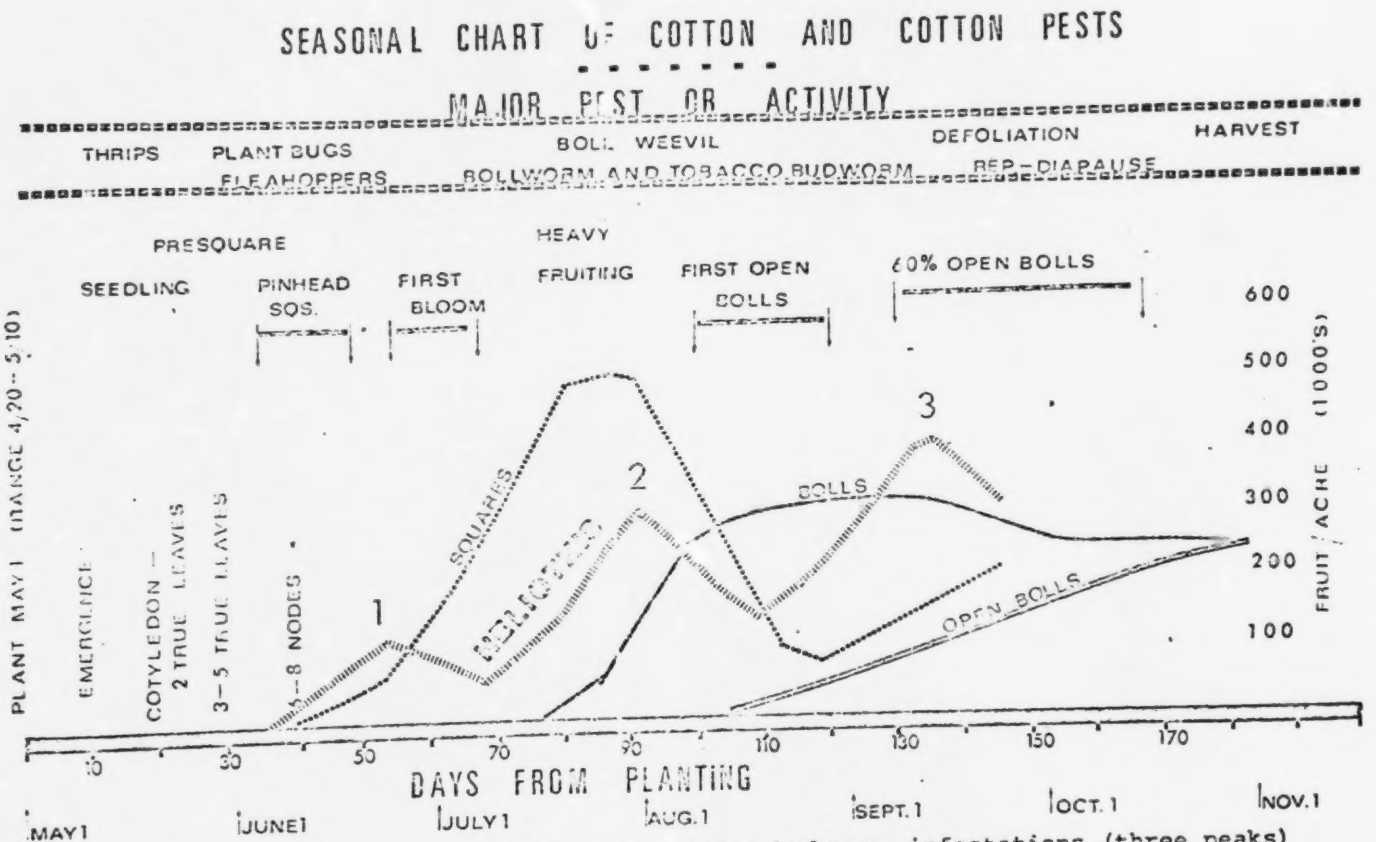

Figure A5.-Helicthis spp., bollworm and tobacco budworm, infestations (three peaks) during the growing season shown on the chart of cotton development.

Source: (18)

they enter hibernation sites to spend the winter. The minimum requirement is one insecticide application with the defoliant in areas where weevil populations are low and the crop does not produce regrowth after defoliation. In most cases the maximum fall program would consist of 4 applications: 1 between the last in-season treatment and defoliation, 1 with the defoliant, and 2 applications at 10-14 day intervals after defoliation. A program which will fit many cases would be 1 application between the in-season treatment and defoliation, 1 application with the defoliant and 1 application 10-14 days after defoliation for a total of 3 applications (indicated on Figure 4 by "X's" in late season). At the present time, the reproduction-diapause boll weevil control program is the best method available for reducing the need for in-season insecticides.

COTTON INSECT CONTROL PROGRAM:

The history, current status and future progress of insect pest management, with special reference to cotton, was presented by Dr. L. D. Newsom at a Summer Institute on Biological Control of Plant Insects and Diseases held at Mississippi State University in June of 1972 (36). His presentation is the basis for this section of this paper.

Preventative (Scheduled) Insecticide Applications

The demonstration that calcium arsenate gave good control of the boll weevil (8,33) set the stage for applied entomology to rely too heavily on chemical insecticides. The period between the end of World War I and the end of World War II was characterized in cotton insect control by various degrees of success with calcium arsenate. The synthetic organic insecticides which were introduced after World War II were highly effective and revolutionized cotton insect control and growers began to depend heavily upon them for cotton insect control (DDT, Benzene hexachloride, Toxaphene, Chloradane, Aldrin, Heptachlor, Dieldrin, and Endrin). "Ecological principles of animal population regulation were generally forgotten or completely ignored for almost two decades" (36). Use of these insecticides led to the adoption of longer season varieties and cultural practices (irrigation and fertilization) that would have been otherwise unfeasible.

Success with the organic insecticides soon resulted in widespread recommendations by entomologists and acceptance by growers of their use. The resulting cotton insect control program quickly evolved to one of applying insecticides to cotton on a regularly scheduled basis without regard to pest populations or economic injury thresholds. The idea was so attractive to growers because it required little attention to determining economic injury thresholds and so attractive to the insecticide industry because it provided a large and dependable market for their products that it swept across the Cotton Belt. By the early 1950's most of the growers throughout the South had adopted a 'womb to tomb' program of insecticide application beginning with emergence of the seedling plants and ending when the crop had matured beyond the point of susceptibility to insect injury (35). This program was an act of entomological irresponsibility and led to some crisis situations in cotton insect control. The problems which have resulted from too much reliance on chemical insecticides can be summarized as follows (34):

1. Adverse effects on non-target organisms.--The pesticides not only killed the target pests but beneficial insects as well. Residues (environmental pollution) caused delayed and unsuspected effects on birds, fish and other vertebrates.

2. Development of new pests and resurgence of treated population.--The removal of the natural enemies of insects resulted in some previously non-pest species increasing to pest level populations and allowed the target pest species to resurge to population levels that were often higher than pre-treatment levels. These results called for more insecticide treatments.

3. Development of insecticide resistant populations.--The application of chemical pesticides causes selection for the more

insecticide tolerant phenotypes in a breeding population of pest species and eventually leads to a population of individuals that are resistant to the insecticide being used. Insecticide resistance to one or more pesticides has developed in several Midsouth cotton pests including boll weevil, bollworm, tobacco budworm, bandedwing whitefly, aphid, and spider mite. A serious problem of a broad spectrum of insecticide resistance in the tobacco budworm exists at the present time.

These problems have forced a change in attitude and practice in cotton insect control. Today the practitioner is trying to minimize insecticide application reliance as much as possible on natural enemies, and integrating new techniques into his program as soon as they become available. The outlook of research is to develop new integrated cotton insect management strategies for the future.

Prescription (Scouting) Insecticide Program

The current approach to cotton insect management in the Midsouth has three features: (1) scouting of fields by consultant entomologists in order to base insecticide application on economic threshold infestation levels, (2) use of reproduction-diapause boll weevil control in the fall to delay the need for in-season control the next year, and (3) reliance on natural enemies for bollworm and tobacco budworm control, especially in early season. This approach alleviates many of the problems of the 'womb to tomb' program of regularly scheduled insecticides. Environmental pollution is reduced, cost is reduced, insecticide selective pressure is reduced, and beneficial natural enemies are preserved during most of the season reducing the new pest and pest resurgence problem. However, the basic control technique is still a chemical insecticide. Control failures because of insecticide resistance are still occurring. The problem of insecticide resistance in the tobacco budworm causes serious local problems each year. New techniques are needed.

Pest Management (Integrated Program)

If our past and current techniques (basically insecticidal) have been and/or show signs of becoming ineffective, then new approaches of cotton insect management must be developed.

The most promising solution to insect pest problems on cotton is the integration of several control tactics into an insect pest management system (16, 35). The features of a visualized insect pest management system for cotton are outlined as follows:

1. Advantageous use of the innate capacity of cotton to compensate for substantial amounts of injury by Heliothis spp. and other species without reduction in yield or quality (1, 2, 23, 24, 44, 45).
2. Advantageous use of natural factors (especially predators and parasites) that regulate Heliothis spp. and other pest populations (47).
    - a. Conservation through minimum use of insecticides (28).
    - b. Conservation and augmentation by habitat modification and provision of supplemental food sources (14, 25).
    - c. Production and supplemental releases (40).

   d. Importation and colonization of exotic species of predators and parasites (12, 22, 41, 43).

3. Use of insect resistant characters in commercial varieties of cotton (31, 42).

4. Use of selective insecticides, microbial biocides, and other regulating agents such as pheromones, to control pest species with least adverse effect on non-target organisms (3, 13, 20, 32, 39).

5. Use of cultural control measures to reduce boll weevil and Heliothis populations or to escape peak infestation periods (21, 46).

6. Control of the key pest, the boll weevil, by ecologically sound methods which have minimal effect on natural enemies of Heliothis spp. and other secondary pests (4, 5, 6, 18, 29, 30).

Most of the components of the visualized insect management system for cotton are in the research stage. A prominent exception is the reproduction-diapause boll weevil control program which has been recommended and implemented in many boll weevil infested areas. Implementation of the reproduction-diapause boll weevil control program allows for maximum use of natural regulation of Heliothis spp. in cotton.

The various components of a cotton insect management system, i.e., natural enemies, microbial biocides, selective insecticides, pheromones, resistant varieties, etc., are not expected to function sufficiently alone to suppress infestations below economically damaging levels. The control techniques which show promise must be integrated into dynamic insect pest management systems to provide the control necessary at a reasonable cost with tolerable environmental consequences. The complexity of the system involved requires the technology of systems engineers and the capability of the computer to optimize insect pest management strategies (17).

POSSIBLE ALTERNATIVES FACED IN COTTON INSECT MANAGEMENT:

The previous discussion has indicated that the past program of unilateral reliance on chemical pesticides not only resulted in some serious control failures, but also had some very undesirable side effects. The current practice of scouting cotton fields, using insecticides only when necessary, and relying on natural enemies as much as possible appears to be inadequate. On the other hand the concept of integrated insect pest management appears to offer promise of long-term solution to our cotton insect problems. In this transition period of crisis, what are some of the possible alternatives that may be faced in the future?

Effective Non-Persistent Insecticides.--Insecticide chemistry may develop new compounds and entomology research may develop them for practical application. If such chemicals were developed with little environmental hazard, we might rely on the current insecticide based approach to cotton insect control for many more years. Actually this would be an easier, probably cheaper approach. However, there is a great deal of risk in such an approach. Assuming that resistance will eventually develop to any new compound, there is the risk that another new insecticide will not be developed in time to take its place.

Effective Pesticides Which Are Restricted Or Prohibited.-- Insect management research and action programs are often justified because of regulations against use of certain needed insecticides. However, it is highly unlikely that a governmental agency will be allowed to restrict use of needed chemicals for any length of time to the extent that significant crop losses occur.

Ineffective Insecticides Because Of Insecticide Resistance.--The capability of insects to develop insecticide resistance has all too frequently been demonstrated. Political pressure cannot return an insecticide to the market when it was lost because of insecticide resistance. The basic structures of pesticide chemicals are limited in their capability to provide new effective insecticides by the alteration of sidegroups or other structural elements. New insecticides may be forthcoming and available when needed, but unless they are on the shelf or under development now, the risk of a crop loss is great. Thus, it is the adaptability of biological systems that we are up against. Cost may not be the key factor. If current cotton insect programs fail, we must have a workable alternative even if it costs more than current techniques. Furthermore, new approaches must be developed before they are needed and estimates of their functionings and costs must be available when implemented.

In conclusion, it should be pointed out that the previous discussions have been related to profitable commercial cotton farms, which are predominant in the Midsouth, and not to the marginal and subsistence cotton farms, a few of which are still being operated.

SPECIFIC PROGRAMS

The purpose of this section is to report and evaluate from reported information specific insect management programs for cotton in Mississippi, Alabama, and Louisiana.

Mississippi

In Mississippi, the boll weevil (*Anthonomus grandis*) is the primary pest (37). Other arthropods such as bollworms (*Heliothis zea* and *H. virescens*), spider mites (*Tetranychus urticae*), and cotton aphids (*Aphis gossypii*) are secondary pests because they may increase to economically important infestations following insecticide applications to control woll weevils.

In 1972, boll weevils cost an estimated $28,000,000 to the cotton industry in Mississippi (37). Annual losses to bollworms and other insects were estimated at $15,524,855 and $1,250,000, respectively (37). If early season insecticide applications could be eliminated for boll weevils by diapause control programs, population levels of the predators and parasites of the bollworms and spider mites could assist in maintaining these secondary pests below their economic thresholds.

Historically, Mississippi cotton farmers have used insecticide applications erratically in crop production. Many used 18 to 24 applications and approximately 85% of all insecticides applied in the state have been used on cotton (37).

I. Mississippi, 1972

Specific Program: Grenada-Yalobusha Pest Management Society, Inc.

Characteristics: Objectives listed for the first growing season of the Pilot Pest Management Program in Mississippi: 1. Adoption and acceptance of economic thresholds by farmers for applying insecticides to cotton for pest control; 2. Utilization of naturally occurring biological control agents; and 3. Participation in community-wide boll weevil reproductive diapause control programs. Long range objectives were: 1. Development of pest management programs for expansion to all cotton growing areas of the state; 2. Lower environmental contamination; 3. Slow development of insecticide resistance by insect pests; and 4. Development of pesticide container disposal systems (37).

Users And Location: The Pilot Project was located in the Mississippi Delta and Hill areas of Grenada and Yalobusha Counties. Small portions of Calhoun, Tallahatchie, Lafayette, and Montgomery Counties were also included.

According to ASCS records 12,883 acres of cotton on 549 farms in Grenada County, and 12,974 acres on 1,200 farms in Yalobusha County were planted in 1972. These counties have severe cotton insect control problems each year and a history of high insecticide usuage. Most of the cotton was not scouted prior to 1972, and many of the farmers were using an automatic or insurance type of control program. Only a few of the farmers had previously participated in a good community-wide boll weevil reproductive-diapause control program.

Most of the fields in the project area are relatively small (average of approximately 10-12 acres). In order to obtain adequate acreage most producers rent the majority of the land they farm. One producer in the program worked 53 fields on 23 farms for a total of 600 acres in 1972. Average acreage per producer was approximately 148, with the smallest producer farming 3.0 acres and the largest 909. Most fields in the area were surrounded by trees (predominantly hardwoods) which made proper aerial applications of insecticides difficult. This type of terrain provided an abundance of ideal overwintering sites for boll weevils.

A total of 15,963.2 acres (61% of the planted acreage) was scouted in the program and 12,270.7 acres (46% of the planted acreage) was involved in a boll weevil diapause control program (37).

Biological Effectiveness: The project area is comprised of 10 communities, each characterized by slightly different topography and farming practices. The highest level of weevil infestation occurred in the Skuna Valley Community. This community is located in the hill section of Yalobusha County, and farmers in this community have never conducted a community-wide boll weevil diapause control program. In contrast, 80% of the farmers in Holcomb (a community located in the delta section of Grenada County) have at least added insecticide to their defoliant for the last two years. Results of their efforts are reflected by the lower level of weevil infestation in Holcomb as compared to surrounding communities.

Bollworm pressure was relatively light this year (1972) and all producers were able to withstand the first generation, which occurred in late July, without resorting to insecticidal control measures. Second generation bollworms did cause problems in a very small percentage of the fields in the area, but most farmers were able to tolerate this generation also without resorting to chemical control. Approximately 40% of the producers never applied insecticide for wollworm control (37).

Types And Amounts Of Costs: Members of the society paid for a scouting program at the rate of $1.25 per acre. This program was supervised by extension personnel. Other reported costs are discussed later.

Environmental Impact: The results of properly timed insecticide applications taken from data collected during the scouting period shows conclusively that growers who relied on scouting reports and economic threshold concepts were able to maintain lower boll weevil populations throughout the entire season than did non-cooperators.

Non-cooperators averaged 13.4 applications per acre, whereas cooperators averaged 10.6 applications per acre. Reduction in the amount of pesticide being added to the environment is obvious; cooperators averaged 2.8 fewer applications than did non-cooperators (37).

Overall Feasibility: Although no reported information on the economics of the program is available, certain information can be inferred from the collected data. If the total acreage sprayed (as determined by records of aerial applicators) is divided by the total planted acreage, it is apparent that non-cooperators averaged 13.4 applications per acre, whereas cooperators averaged 10.6 applications per acre. At an average cost of $1.25 per acre (.25# Methyl Parathion applied aerially), this means that cooperators spent $13.25 per acre for inseason (does not include cost of diapause control) insect control as compared to $16.75 per acre spent by non-cooperators; a savings of $3.50 per acre. The $3.50 per acre savings is actually a very conservative estimate since many non-cooperators were using bollworm insecticides in addition to the .25# Methyl Parathion in an insurance type program.

There appears to be much reason for optimism that an effective, economical, multifaceted pest management system can be developed for this region (37). However, there are apparent signs of potential roadblocks to the successful development of the pest management concept. Those that appear most significant are the following:

1. Lack of sufficient numbers of trained personnel.
2. Current attitudes of the insecticide industry, commercial applicators and growers.
3. Cooperation between members of all disciplines involved in crop production.
4. Difficulties in developing and registering for use insecticides that are especially needed in pest management (35).

Other problems encountered are as follows: 1. Convincing the producers to accept the economic threshold concept; 2. Obtaining information on their insecticide applications; 3. Requests from the producers for more personal attention by the project staff; and 4. Early termination of the scouting program as a result of school starting early.

However, in spite of these problems a great deal was accomplished during the first year of operation. Perhaps the greatest accomplishment was gaining the respect and confidence of the producers (37).

Statewide Program, 1972

Pest management principles and techniques in cotton production were promoted throughout Mississippi during 1972. Three television programs and six radio programs were developed and used specifically for this purpose.

Five cotton scout training seminars were held in the state. Approximately 120 young men were trained to work as cotton scouts (pest monitors) with various programs (federal and county), with private agricultural consultants and pesticide companies. Cotton scouting was discussed and limited training was given to approximately 300 private cotton producers. Three counties implemented new scouting programs in 1972 and training was given all county agents in pest management techniques.

Assistance was given to county agents in the development of boll weevil diapause programs in eight counties in Mississippi that had not had previous programs.

An annual pest management workshop was implemented. It was designed to share knowledge in pest management techniques among researchers and other people involved in agricultural consulting in the fields of arthropod, disease and weed control. One hundred and forty-five attended the first workshop.

A special handout sheet for farmers was developed on container disposal. A number of counties (Lee, Montgomery, and Sunflower) developed an insecticide pick-up system and sanitary landfill for solid wastes.

II. Mississippi, 1973

Specific Program: Grenada-Yalobusha Pest Management Society, Inc.

Characteristics: Immediate objectives during 1973 were: 1. Expansion of project area into counties adjacent to the 1972 project area; and 2. Test and refine a pest management program that could eventually be administered and conducted by local county agents and cotton producers (38).

Users And Location: The project area did not differ significantly from 1972. It was centered in Grenada and Yalobusha Counties and included portions of the following counties: Calhoun, Carroll, Lafayette, Montgomery, Panola, and Webster.

Agricultural Stabilization and Conservation Service records indicate that approximately 9,500 acres of cotton are grown on 173 farms in Grenada County and approximately 9,500 acres on 297 farms in Yalobusha County. Most fields in the area are small, averaging approximately 10 acres in size. One producer farmed 250 acres involving 86 fields. In order to obtain adequate acreage most producers rent the majority of the land they farm. Average acreage per producer was approximately 150 acres with a range of 4 to 550 acres. In addition to being small, most fields in the area are surrounded by trees which make proper aerial application of insecticides difficult in some cases.

A total of 13,824 acres were scouted in the program and approximately 6,500 acres were involved in the boll weevil diapause control program (38).

Biological Effectiveness: The project area is comprised of 12 communities. The highest level of boll weevil infestation occurred in the Water Valley Community whose farmers have never conducted a community-wide boll weevil diapause control program.

Bollworm pressure was greater in 1973 than in 1972. However, a few producers never had to resort to insecticide applications specifically for bollworm control. All producers were able to tolerate the first generation which occurred in late June without resorting to insecticide control measures. Second generation bollworm did cause localized problems but most producers were able to withstand this generation without resorting to chemical control. The third generation (mid-August) forced most producers to apply insecticides for bollworm control.

Types And Amounts of Costs: Producers paid $1.25 per acre for a scouting program. Other reported costs are discussed later.

Environmental Impact: Repetitive and systematic samples were collected to determine the presence and amount of residual pesticides. The samples were shipped to USDA, APHIS, PP and OP Environmental Quality Laboratory at Brownsville, Texas. Analyses of the samples are incomplete at the present time (38).

Overall Feasibility: A pilot pest management program on cotton was initiated in 1972 and continued in 1973. Weekly counts of harmful and beneficial insects were made by 13 scouts. Control recommendations were made based on insect counts determined by the scouts. Producers who strictly adhered to these recommendations averaged 9.8 insecticide applications per acre for regular season boll weevil and bollworm control. Producers in the project area that did not participate in the program averaged 12.1 regular season applications per acre.

At an average cost of $1.25 per acre (.25# Methyl Parathion applied aerially), this means that non-cooperators averaged $15.12 per acre for insect control. On the other hand, cooperators averaged $12.25 per acre for inseason insect control (a savings of $2.87 per acre). This $2.87 per acre saving is actually a very conservative estimate since many non-cooperators used bollworm insecticides on higher rates for control of boll weevil infestations when less expensive insecticides and/or lower rates would have been equally effective.

Reduction in the amount of pesticides being added to the environment is obvious; cooperators averaged 2.3 fewer applications than did non-cooperators. No data are shown concerning types or rates of pesticides used, but the use of persistent insecticides and/or high rates of non-persistent insecticides in insurance-type spray programs for bollworm control was very prevalent among non-cooperators.

In addition to a scouting program the 1973 project involved a boll weevil reproductive diapause control program. Participating producers signed an agreement making it virtually impossible to withdraw from the program. As a result, a block containing 6,500 acres of cotton received four applications of Methyl Parathion after termination of the regular season insect control program.

A pesticide container disposal campaign was initiated in order to provide ecologically acceptable disposal sites for empty pesticide containers. Criteria for site selection were based on accessibility and soil type conducive to proper disposal. A total of nine sites were prepared in the two county areas. Farmer acceptance of this project was very encouraging.

Statewide Program, 1973

Pest management principles and techniques in cotton production were promoted throughout the state during 1973. Six television programs, 12 radio programs, and 14 news articles were developed and used specifically for this purpose.

Six cotton scout training seminars were held in the state. Approximately 300 young men were trained to work as cotton scouts (pest monitors) with various programs (federal and county), private agricultural consultants and pesticide companies. Cotton scouting was discussed and limited training was given to approximately 300 private cotton producers. Ten counties implemented new scouting programs in 1973 and county agents in at least 8 additional counties indicated that they would initiate scouting programs in 1974. Training was given all county agents in pest management techniques.

Assistance was given to county agents in the development of boll weevil diapause programs in six counties that had not had previous programs.

The annual pest management workshop was held again in 1973. This conference was designed to share knowledge in pest management techniques among researchers and other people involved in agricultural consulting in the fields of arthropod, disease and weed control. One hundred and eighty-three attended this 2-day workshop.

A close working relationship with aerial applicators was established. Support for pest management techniques was gained from aerial applicators and their association.

Assistance was given in the development of a special publication on pesticide safety for distribution to farmers throughout the state. Proper application methods, reentry, protective clothing and pesticide container disposal were among the topics presented in this publication. A number of counties developed an insecticide pick-up system and sanitary landfill for solid wastes.

Alabama

In Alabama, as in Mississippi, the boll weevil (Anthonomus grandis) is the key cotton insect pest; however, the bollworm complex sometimes causes as much or more damage as the boll weevil (27).

I. Alabama, 1972

Specific Program: 1972 Alabama Cotton Pest Management Program

Characteristics: Under the 1972 Alabama Cotton Pest Management program 38,759 acres were scouted by 27 scouts. Three scout supervisors were utilized to provide on-the-scene interpretations of field insect infestation data. The scout supervisor was the key link between the scouts, county agents and extension entomologist's office. The supervisors provided an added dimension to the scouting program in 1972. Each of these men had prior experience as a cotton insect scout plus a B. S. degree in an agriculturally related field. These men worked out of the county extension office and were well accepted by the extension staff, farmers and scouts. In addition to providing technical guidance to the scouts in the field, the supervisors held weekly meetings with the scouts and county extension staff.

The 27 scouts scouted 1,433 fields weekly for an average of slightly over 1,400 acres per scout. An additional 5,700 acres were scouted weekly by growers. These growers attended the scouting shortcourse and were furnished scouting forms for their use in recording infestation data. A total of 44,700 out of the approximately 50,000 acres in the 6-county area were scouted weekly. Five of these counties had never had a scouting program previous to 1972.

Scouts completed a "field infestation report" for the farmer each week after scouting his fields. This form was prepared in quadruplicate and the county [illegible] chairman, scout supervisors and extension entomologist also received copies. Pest population data were obtained from 696 fields covering 16,908 acres in the pest management area and an additional 363 fields in 10 other counties with a total of 11,570 acres. This data was compiled and computerized with print-outs weekly. The pest population and other data was coded for computerization by either the scout supervisors or secretaries in the state office. A special cotton pest management newsletter was developed and mailed weekly to all growers, scouts, supervisors, county extension agents, industry representatives, and various news media in Alabama. A great deal of interest developed in this letter with county agents and growers throughout the state (26).

Users And Location: The Alabama Pest Management Program is centered in three Central Alabama and three Western Alabama Counties. The counties located in the western part of the state are Pickens, Fayette, Tuscaloosa and the northern section of Hale. Those counties located in the central part of the state are Chilton, Autauga, Elmore and the southeastern section of Macon. These two areas were chosen because of the severity of the insect infestations and the current trend of insecticide usage. Commercial growers in these counties utilize from 14 to 16 applications per acre each season. Approximately 50,000 acres of cotton are grown in these six counties. Of the 50,000 acres, 332 farmers with a total of 38,759 acres (78%) participated in the scouting program, and 42,500 acres (comprising 85%) participated in the diapause program. The county extension chairman provided the leadership at the county level in all counties involved.

In addition to these 6 counties, a scouting program was active in 26 additional counties in Alabama. The Extension Service trained scouts (158 state wide) who scouted over 240,000 acres in 32 counties. This amounted to over 35% of the total cotton acreage in the state (26).

Biological Effectiveness: In Alabama most farmers apply a systemic insecticide applied in-furrow at planting time. In 1972 this gave good control of early-season insects, particularly thrips and aphids. Therefore, these insects were not a serious problem. Rainfall was adequate over most of the state through the month of July. Boll weevils emerged earlier and in much higher numbers than in recent years as a result primarily of the mild winter of the previous year. Overwintering weevil counts in seedling cotton were extremely high. Early season square damage at the economic level appeared earlier than usual.

The boll weevil was definitely the "key pest" for cotton farmers in 1972. Even though the infestation counts ran high, most farmers were able to reduce insecticide cost by scouting their cotton and only applying insecticides when an economic infestation occurred. Growers were fortunate in the fact that bollworms did not present a serious problem. Due to the limited number of insecticides available to control the bollworm, farmers must use all available pest management techniques.

Spider mites and whiteflies caused cotton growers much concern in 1972 and in some locations were the greatest insect problem encountered by growers. Both of these pests are becoming more of a problem each year and their management is becoming more important because of the limited number of effective insecticides available to the cotton grower for their control (26).

Types And Amounts of Costs: The cotton farmers paid a $1.00 per acre (the entire cost) for the scouting service (26). Other reported costs will be examined later.

Environmental Impact: Sample sites were selected from cotton fields, adjacent area and fish ponds near cotton fields in Tuscaloosa, Pickens, Autauga, and Elmore Counties to determine the impact of the Cotton Insect Control Program on various components of the environment.

Samples were collected three times from the same site as follows: two weeks before the Insect Control Program started, after the regular insecticide application season was complete, and the third sampling was obtained after the diapause program was complete. The samples were analyzed for pesticide residue by the Alabama Pesticide Residue Laboratory.

A total of 327 samples of soil, forage, water, sediment, fish, quail, rabbit and insect-eating birds were collected according to specific instructions and analyzed for residue content.

Samples of fish, rabbits, quail and other birds were incomplete as a result of difficulty of collecting samples, inclement weather and insufficient time for collecting. However, current plans indicate that such data will be combined and statistically evalued to determine the impact on the various environmental components after three years of data collection (26).

Overall Feasibility: An accurate number of insecticide applications during 1971 could not be ascertained (26). A survey of the farmers indicated that on the average two fewer applications of insecticides were made in 1972 than in 1971. Some farmers reduced the number of applications even more, but an average reduction for all 39,000 acres in the six county pest management was two. At the rate of $2.00 per application, a total of $4.00 per acre on insecticide cost was saved by the farmer. This was enough to pay for the scout and have $3.00 per acre left for diapause control. This resulted in a savings to growers of over $159,000 in the pest management areas.

This savings was a direct result of the insect scouting program. According to data collected during the summer nearly all growers delayed their control programs to later than usual in the season. This lack of early season insecticide applications enabled beneficial insects to remain in the fields longer and this was one factor responsible for the absence of bollworms in Alabama during the 1972 growing season. Both of the bordering states, Mississippi and Georgia, experienced much more severe bollworm pressure than did Alabama throughout the 1972 season. Yields were higher than the state average in each of the counties in the pest management area. This emphasizes the fact that not only is the proper insecticide and amount important, but also the timing of these insecticide applications. This can only be accomplished by pest population assessments made by well trained cotton insect scouts.

The Pest Management Program was an excellent one as evidenced by enthusiasm on the part of the growers and all others with an interest in the program. All major objectives were accomplished. Cooperation from all agencies was excellent. It is felt that a significant economic and environmental impact from this program will be apparent in future years (26). Almost 100% of the farmers who participated in the program in 1972 will do so again in 1973. In addition, some farmers who were skeptical of the program and did not participate will do so in 1973.

II. Alabama, 1973

Specific Program: 1973 Alabama Cotton Pest Management Program

Characteristics: In 1973, 9 scout supervisors were employed to provide continuous field training throughout the scouting season. Pest population data of both destructive and beneficial insects were obtained from 1,053 selected fields totaling 26,379 acres in the 17-county pest management area. This information was computerized along with pesticide usage, cultural practices, phenological data and other background data on each of these selected fields. Weekly print-outs were obtained from this computerized information and a weekly cotton pest management newsletter was prepared for growers, scouts, and other interested persons and groups.

Overwintering boll weevil populations were monitored with the use of pheromone baited Leggett traps during May and June. An organized diapause program was conducted on 4,000 acres and many growers applied one or two applications on an individual basis in late September and October in the 17-county area (27).

Selected ecological components of the environment were monitored from the pest management area at three different time periods during the year.

Users And Location: The Alabama Cotton Pest Management Program was expanded from 6 to 17 counties in 1973. These additional counties were also chosen because of the severity of the insects and the current trend of insecticide usage. Approximately 290,000 acres of cotton are grown in these 17 counties and 599 farmers with a total of 115,000 acres were scouted in 1973 by 73 scouts.

The 17 counties were divided into 4 areas. Area I consists of Tuscaloosa, Pickens and Fayette Counties. Area II consists of Autauga, Chilton and Elmore Counties. Area III consists of Cherokee, Lawrence, Limestone, Madison, Jackson, Colbert and Lauderdale Counties. Area IV consists of Talladega, Hale, Etowah, Dallas, Russell, and Lee Counties. Three thousand, two hundred, eighty fields were scouted in the 17-county pest management area by the 73 scouts for an average of 45 fields per scout.

A scouting program was also conducted in 14 additional counties for a total of 31 counties in Alabama. Over 200 scouts and growers attended two 3-day scouting shortcourses. In addition, five 1-day in-season training programs were held for scouts and growers (27).

Biological Effectiveness: In Alabama, 1973 was an unusual year for cotton producers. Land preparation for planting was delayed by the late harvest in 1972, and the above normal rainfall in the spring of 1973. Therefore, most of the cotton was planted approximately two weeks late. Boll weevils emerged about their normal time in May and June, and apparently migrated in large numbers in search of early cotton (27). As a result the earliest planted cotton had high weevil populations in early season. Once in-season controls were initiated, boll weevils were held in check in most fields for the balance of the season.

Bollworms were a problem in 1973. Infestations occurred in heavy numbers but were sporadic in locations in early August and in September. Poor controls were obtained from insecticides in many instances. The poor control may have been due to poor coverage, improper timing, insufficient amounts of insecticide applied, or to the development of resistance (27).

Types And Amounts Of Costs: Five hundred and ninety-nine growers participated in the pest management program and paid the full cost of $1.25 per acre for the scouting service. Other reported costs will be examined later.

Environmental Impact: Samples of soil, forage, rodents, bees, water, sediment, fish, quail, insect eating birds, and rabbits were collected and analyzed by the Alabama Pesticide Residue Laboratory. Reported information from these samples is still incomplete (27). However, DDT residue is declining. Additionally, no Methyl Parathion is detected before in-season insect control begins. However, samples collected during the in-season control period and after the diapause program contain residual Methyl Parathion.

The level of DDT in fish ponds showed a definite decline. However, Endrin, Methyl Parathion and Toxaphene were found in fish pond samples. No fish kills were observed although some of the pesticides were at levels considered toxic to fish.

Five colonies of honey bees were located at distances of 528 feet, 3,168 feet, 4,752 feet, 5,200 feet, and 19,536 feet from cotton fields in Autauga County on June 26, 1973. No observable differences in worker bee activity were noted in any of the hives except for a few days following the time when a colony was damaged by insecticides. That all colonies suffered bee kills from insecticides was indicated by excessive numbers of dead bees in front of the hives from late July to late August. Comb honey was taken from hives and analyzed for insecticide residues before cotton was treated for pests and at the end of the in-season pest control period. No significant residue was found in any sample.

Overall Feasibility: Excellent progress has been made in convincing growers to apply insecticide applications based on economic threshold levels as determined by field scouting. One advantage of cotton scouting in Alabama is that a grower can delay his initial application from two weeks to a month by observing the pest population in his fields. Otherwise the average grower must begin using insecticides in mid to late June as insurance in order to provide an adequate return on the high investment in his crop (27).

Growers in all areas of Alabama did a good job of managing their insect pests in 1973. However, in Alabama once the initial insecticide application is applied, it is almost impossible to discontinue applications during the major fruiting season due to the tremendous pressure from boll weevils and bollworms.

Growers who participated in the program applied 2 to 4 fewer applications than growers who made insecticide applications on a calendar schedule. Each insecticide application reduction resulted in a saving of over $2.00 per acre to Alabama cotton growers (27). Additionally, growers who participated in the pest management program, harvested yields above the state and county average (27). The increased yield was probably due to insect management, use of recommended cultural practices, and superior management in all phases of crop production.

Louisiana

Unlike the programs in Mississippi and Alabama, the only information available for the Louisiana insect management program for cotton is for the 1972 crop season. The pest complex of cotton in Louisiana includes the boll weevil (*Anthonomus grandis*), bollworm (*Heliothis zea*), tobacco budworm (*H. virescens*), cotton fleahopper (*Pseudatomoscelis seriatus*), tarnished plant bug (*Lygus lineolaris*), bandedwing whitefly (*Trialeurodes abutilonea*), cotton aphid (*Aphis gossypii*), cabbage looper (*Trichoplusia ni*), spider mites and thrips (several species). The boll weevil is the key insect pest on cotton in Louisiana.

The insect problem in Louisiana is of such magnitude that cotton cannot be produced profitably without pest suppression techniques and insecticides are currently the only line of defense against cotton pests (8). Historically, once a control program is started in cotton, it is generally continued on a regularly scheduled basis throughout the remainder of the growing season, even though infestation and/or damage estimates do not indicate the need for it. As many as 20 insecticide applications have been made by some growers.

Approximately two-thirds of the cotton produced in Louisiana is commercially scouted, some on a regular (weekly) basis and a great deal only when the grower can find someone to do it. Sampling techniques for infestation and damage estimates and quality of the scouting itself are almost as numerous as are the scouts.

Louisiana growers have not yet been made to realize the important potential that beneficial arthropods and sound cultural practices can play in cotton pest management. They have not grasped the potential hazard, physically (from an environmental standpoint) as well as production wise, and/or the legal ramifications associated with their current 'womb to tomb' philosophy on pest suppression in cotton (8).

I. Louisiana, 1972

Specific Program: Louisiana Cotton Pest Management Pilot Project

Characteristics: Objectives listed for the first growing season of the Pilot Pest Management Program in Louisiana were:

1. To help cotton producers adopt insect pest management techniques for cotton that will yield optimum protection at a minimum production cost with a minimum amount of environmental contamination.
    a. Utilization of economic thresholds to make insecticide applications only when and where needed.
    b. Make use of naturally occurring biological control agents.
2. To train a corps of cotton producers, pest management assistants, commercial entomologists, etc. to serve as a nucleus to extend the pest management concepts to other parts of the State.
3. To obtain farmer adoption of a boll weevil reproductive-diapause control program as quickly as possible.

Users And Location: The Louisiana Cotton Pest Management Program was conducted in portions of Catahoula, Grant and Tensas parishes in 1972. These parishes represent the major cotton farming areas of Louisiana. In 1972, 70 producers (5,600 acres) participated in the program.

Biological Effectiveness: In Louisiana, usually Heliothis larvae collected from cotton during June and early July are H. virescens and H. zea is the predominant species the remainder of the season. In 1972, however, the majority of larvae collected from cotton during August and September was H. virescens. This was also true among collections made within the Pest Management Program Areas. H. virescens larvae were difficult to control in many areas of the state during this time and subsequent monitoring for insecticide resistance demonstrated six of seven cultures assayed possessed high levels of resistance to Methyl Parathion (10-30 fold) and somewhat lower levels of resistance to Toxaphene plus DDT (2-10 fold). This information at the producer level will enhance support and success of the Pest Management Program in 1973.

Types And Amounts Of Costs: The reported costs for the scouting program was $2.45 per acre (8). The scouts (and all other costs associated with scouting) were paid entirely from project funds of 1972. Scouting was provided as a free service to participating farmers. Other costs will be discussed later.

Environmental Impact: Beneficial insect population were sampled on a weekly basis until one week after the first full insecticide application in each field. Information on beneficial populations was provided to the producers. Their interest in such information offers an excellent potential to convince growers to delay their initial application as long as possible.

Overall Feasibility: During the first year of the Pest Management Program in Louisiana, many problems were encountered in developing, organizing and operating the program. These problems may have resulted from the late funding and consequently the late implementation of the program. Problems associated with limited scout training, lack of advance publicity of pest management principles and concepts, and failure to organize producer groups could possibly have been eliminated or certainly reduced had the program begun earlier.

Some of the acreage selected for the program was also scouted by a commercial scouting service. Throughout the season variations occurred in the field reports. Often these differences could be justified on the basis of the time interval between the counts since infestation or damage levels and population estimates can change in three to five days. However, sometimes large differences occurred among field reports taken within two days of each other, and the producer was confronted with two very different sets of information from which to make control decisions. Sampling technique, sample size, field reporting forms, etc. should be standardized as much as possible. Plans are currently underway to determine how this can be achieved in 1973.

Other problems encountered were as follows:

1. Convincing producers to accept economic threshold concept.
2. Getting the producer to participate in data accumulation.
3. Acceptance of a community-wide boll weevil diapause effort.
4. Early termination of the scouting program.
5. Work time lost due to widely separated fields.

INSECTICIDE MATERIAL AND APPLICATION COSTS

To this point costs discussed have been those reported by the individuals involved in the specific pilot programs. Because various insecticides, insecticide costs and tractor and equipment costs have been assumed by the researchers involved, comparisons among programs and against some standard is difficult. Also, it is important to note that none of the programs were designed for economic analysis at the end of the second year. And, specific insecticides and rates are not generally reported.

To offset this difficulty, a standard[2] will be established and all costs will be fixed (set constant for all programs and years) at 1972 levels. To establish the standard and place insecticide costs in perspective consider the cotton budget in Table A1. Table A1 approximates the cost of producing cotton in the Midsouth in 1972 for those producers using a calendar or 'womb to tomb' type insecticide program (6 row type equipment and 80-90 hp. tractor is implied). The budget presented in Table A1 was generated from reported information (7, 9, 26, 27, 37, 38) and from personal observations of the author. The insecticide program detailed in Table A1 includes 20 insecticide applications. The program includes a systemic insecticide (Di-Syston) applied at planting and an aerial application of Bidrin applied early in the season for thrips. Seven applications of 1.0 lb. Toxaphene

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[2] The standard for comparison will be a calendar or 'womb to tomb' type insecticide program. The calendar type insecticide program was the dominant type utilized by cotton farmers in the Midsouth during the 1960's and early 1970's.

Table A-1. Approximate cotton production costs per acre, 6-row equipment, solid planted, and usual [1] farm practice, Midsouth, 1972.

Operation	Times over	Tractor Cost Direct	Tractor Cost Fixed	Equipment Cost Direct	Equipment Cost Fixed	Labor cost [2]	Mat. cost	Misc. cost	Total
		Dollars							
Apply P and K	1.0	.16	.10	.07	.15	.23	4.79	-	5.50
Chisel plow	1.0	.37	.24	.12	.25	.36	-	-	1.34
Subsoiler	1.0	1.55	.99	.21	.31	1.50	-	-	4.56
Middle breaker	1.0	.37	.24	.12	.22	.36	-	-	1.31
Apply nitrogen	1.0	.43	.28	.12	.23	.63	2.26	-	3.95
Condition seedbed	1.0	.31	.20	.04	.07	.30	-	-	.92
Pul. Disc./herbicide	1.0	.39	.25	.23	.37	.38	2.53	-	4.15
Condition seedbed	1.0	.31	.20	.04	.07	.30	-	-	.92
Plant/premerge	1.0	.37	.24	.21	.44	.72	4.28 [3]	-	6.26
Insecticide-air	1.0	-	-	-	-	-	.34 [4]	.85	1.19
Cult-postem early	1.0	.39	.25	.09	.16	.38	1.40	-	2.67
Hand weed control	1.0	-	-	-	-	5.25	-	-	5.25
Cultivate	1.0	.39	.25	.08	.13	.38	-	-	1.23
Cult-postem late	1.0	.31	.20	.10	.20	.30	1.28	-	2.39
Hand weed control	1.0	-	-	-	-	3.75	-	-	3.75
Cult and lay by herb.	1.0	.37	.24	.09	.17	.36	1.28	-	2.51
Insect-Highboy	7.0	1.12	.70	1.26	1.47	1.05	7.00 [5]	-	12.60
Insect-Air	8.0	-	-	-	-	-	16.00 [6]	6.80	22.80

Table A-1. Contd. Approximate cotton production costs per acre, 6-row equipment, solid planted, and usual[1] farm practice, Midsouth, 1976.

Operation	Times over	Tractor Cost		Equipment Cost		Labor cost[2]	Mat. cost	Misc. cost	Total
		Direct	Fixed	Direct	Fixed				
		-Dollars-							
Insect-Air	2.0	-	-	-	-	-	2.00[7]	1.70	3.70
Insect-Air	1.0	-	-	-	-	-	.90[8]	.85	1.75
Defoliate	1.0	.16	.10	.18	.21	.15	1.28	-	2.08
Cotton pick-first pk.	1.0	-	-	7.81	12.84	2.50	-	-	23.15
Cotton pick-second pk.	.5	-	-	4.96	8.15	1.58	-	-	14.69
Haul-first pk.	1.0	.60	.72	.30	.78	.75	-	-	3.15
Haul-second pk.	1.0	.15	.18	.08	.19	.19	-	-	.79
Stalk shredder	1.0	.37	.24	.05	.18	.36	-	-	1.20
Total									133.79

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[1] Normal field operations. However, a calender type insecticide program is assumed.

[2] $1.50 per hour.

[3] Includes insecticide material cost of $1.00 (4.0 lb. of Di-Syston at $.25/lb.)

[4] Insecticide material (.1 lb. of Bidrin at $3.40/lb.)

[5] Insecticide material (Toxaphene & Methyl Parathion mixture-each application includes 1.0 lb. of Toxaphene at $.50/lb. and .5 lb. of Methyl at $1.00/lb.)

[6] Insecticide material (Toxaphene & Methyl Parathion mixture-each application includes 2.0 lb. of Toxaphene at $.50/lb and 1.0 lb. of Methyl at $1.00/lb.)

[7] Insecticide material (each application includes 1.0 lb. of Methyl at $1.00/lb.)

[8] Insecticide material (.12 lb. of Fundal at $7.50/lb.)

plus .5 lb. Methyl Parathion and 8 applications of 2.0 lb. Toxaphene plus 1.0 lb. Methyl Parathion applied for boll weevil and bollworms, and 2 applications of Methyl Parathion for boll weevil and bollworms plus one application of Fundal (ovicide). The program cost $43.04 per acre (cost of insecticide plus cost of application). The program calls for 4.0 lb. of Di-Syston, .1 lb. of Bidrin, .12 lb. of Fundal, 13.5 lb. of Methyl Parathion, and 23.0 lb. of Toxaphene. This insecticide program represents 32% of production cost, and will be used as the standard for approximating the effectiveness of specific programs presented earlier. The specific programs generally reported the number of insecticide applications but not specific insecticides used or their rates. The insecticides used to represent the specific pilot program under discussion are based on personal observations of the author. It should be noted that most insecticides have substitutes. However, substitutes tend to cost approximately the same as the chemical they replace. Consequently, the cost of a specific insecticide program is generally not sensitive to the particular set of chemicals used in the program.

Participants in the pilot program in Alabama utilized 12 to 14 insecticide applications in 1972 (26) and 8 to 10 applications in 1973 (27). Participants in the Mississippi pilot program applied an average of 10.6 applications in 1972 (37) and 9.8 applications in 1973 (38). An average of 13 applications was assumed for the participants in the pilot program in Louisiana. Table A2 compares representative insecticide programs for the pilot area for each year against the standard discussed earlier.

Table A-2. Calendar insecticide program and representation insecticide program for Mississippi, Alabama, and Louisiana Pilot Areas.

Insecticide	Price per lb.	Rate	Method	Calendar			Mississippi 1972			Mississippi 1973		
				Times over	Mat.	Total cost1/	Times over	Mat.	Total cost	Times over	Mat.	Total cost
	Dol.	lb.			lb.	Dol.		lb.	Dol.		lb.	Dol.
Di-Syston	.25	4.00	At Plt	1.0	4.00	1.00						
Bidrin	3.40	.10	Air	1.0	.10	1.19	1.0	.10	1.19	1.0	.10	1.19
Toxaphene & Methyl Parathion	.50 1.00	1.00 .50	Highboy	7.0	7.00 3.50	12.60	5.0	5.00 2.50	9.00	4.0	4.00 2.00	7.20
Toxaphene & Methyl Parathion	.50 1.00	2.00 1.00	Air	8.0	16.00 8.00	22.80	4.0	8.00 4.00	11.40	4.0	8.00 4.00	11.40
Methyl Parathion	1.00	1.00	Air	2.0	2.00	3.70	1.0	1.00	1.85	1.0	1.00	1.85
Fundal	7.50	.12	Air	1.0	.12	1.75						
Total				20.0		43.04	11.0		23.44	10.0		21.64
Total Toxaphene					23.0			13.0			12.0	
Total Methyl Parathion					13.5			7.5			7.0	

1/ Cost of insecticide plus cost of application. Di-Syston is applied at planting-no application cost is assumed.

Table A-2. Calendar insecticide program and representation insecticide program for Mississippi, Alabama, and Louisiana Pilot Areas.

Insecticide	Alabama 1972			Alabama 1973			Louisiana 1972		
	Times over	Mat.	Total cost	Times over	Mat.	Total cost	Times over	Mat.	Total cost
		lb.	dol.		lb.	dol.		lb.	dol.
Di-Syston									
Bidrin	1.0	.10	1.19	1.0	.10	1.19	1.0	.10	1.19
Toxaphene & Methyl Parathion	6.0	6.00 3.00	10.80	4.0	4.00 2.00	7.20	4.0	4.00 2.00	7.20
Toxaphene & Methyl Parathion	6.0	12.00 6.00	17.10	3.0	6.00 3.00	8.55	5.0	10.00 5.00	14.25
Methyl Parathion	1.0	1.00	1.85	1.0	1.00	1.85	2.0	2.00	3.75
Fundal							1.0	.12	1.75
Total	14.0		30.94	9.0		18.79	13.0		28.09
Total Toxaphene		18.0			10.0			14.0	
Total Methyl Parathion		10.0			6.0			9.0	

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[1] Cost of insecticide plus cost of application. Di-Syston is applied at planting-no application cost is assumed.

Without exception, the insecticide program utilized in the Mississippi, Alabama, or Louisiana pilot areas cost less and resulted in fewer pounds of insecticides than a calendar type insecticide program. Table A2 indicates that the 1972 insecticide program for participants in the pilot area in Mississippi cost $23.44 per acre (a reduction of $19.60 per acre), Toxaphene utilization was reduced from 23.0 lb. to 13.0 lb. per acre, and Methyl Parathion was reduced from 13.5 lb. to 7.5 lb. per acre. The cost of the insecticide program for participants in the pilot area in Mississippi was reduced again in 1973, and the amount of chemical insecticides was also reduced.

In Alabama, participants in the cotton pest management pilot program had insecticide costs of $30.94 per acre in 1972 and $18.79 per acre in 1973 (reductions of $12.10, and $24.85 per acre respectively). Toxaphene was reduced to 18.0 lb. in 1972 and 10.0 lb. per acre in 1973 (reductions of 5.0, and 13.0 lb. per acre respectively). Methyl Parathion was reduced to 10.0 lb. in 1972 and 6.0 lb. per acre in 1973 (reductions of 3.5, and 7.5 lb. per acre respectively).

The insecticide program listed for the Louisiana pilot area for 1972 indicates 13 insecticide applications. It is less expensive than the calendar type insecticide program. Table A2 indicates that the 1972 insecticide program for participants in the Louisiana pilot area cost $28.05 per acre (a reduction of $14.95 per acre). Additionally, Toxaphene utilization was reduced from 23.0 lb. to 14.0 lb. per acre, and Methyl Parathion was reduced from 13.5 lb. to 9.0 lb. per acre.

Reductions in cost of the magnitude presented in Table B2 are economically significant. Farmers will (and are) respond to savings of this size. Additionally, savings of this size are sufficiently large to cover the entire cost of an effective boll weevil diapause program. An effective and economical boll weevil diapause program is probably the key to the management of cotton insect pests in the Mid-south.

SUMMARY

Cotton Pest Management Programs in Mississippi, Alabama and Louisiana are successful. The individuals involved in these programs have demonstrated to the cotton producers in the pilot areas (and other areas) that the cost of an insecticide program for cotton can be reduced while maintaining effective control. Such programs are resulting in less pesticide pollution.

The individuals responsible for selecting the pilot areas are to be commended for selecting areas with severe cotton insect problems. The pilot pest management programs are effecting insecticide programs outside the pilot areas. The number of insecticide applications for cotton production is declining. In 1971, cotton producers in the Midsouth that sprayed on a calendar basis used approximately 20 applications (9). Today, very few cotton producers in the Midsouth adhere to a calendar type spray program for insect control in cotton. Additionally, a few cotton producers in the Midsouth (probably 10-15% of the planted acreage) will produce the 1974 crop with seven or less insecticide applications. This percentage will increase rapidly in the years to come as the research units in the states continue to investigate integrated pest management methods and the Extension Service (in cooperation with other agencies) continue to assist producers in adopting the new techniques.

The National Cotton Council and the United States Department of Agriculture (actually no USDA policy has been formulated and released) have recently proposed a beltwide plan for boll weevil eradication. A modified version calls for a 3-year trial program in the Carolinas or in northern Texas. The proposed program consists of in-season control and reproduction-diapause control with insecticides, use of grandlure (pheromone) in traps and trap crops, and use of sterile boll weevils. The proposed program was tested in 1970-1973 in a Pilot Boll Weevil Eradication Experiment in southern Mississippi. Technical assessments of the experiment's results (Technical Guidance Committee for the experiment and a special Entomological Society of America Committee) indicated the need for improvements in the eradication technology. Scientists have been divided in their judgement of boll weevil eradication capability. In the opinion of the author, the political climate is not favorable for the multimillion dollar (more than $600 million) program. However, a national committment for the development of cotton insect pest suppression techniques for use in integrated pest management systems can yield immediate adaptation and application of these techniques in cotton insect management programs.

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Appendix B-i

EVALUATION OF PEST MANAGEMENT PROGRAMS FOR COTTON IN NORTH CAROLINA AND ARKANSAS

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Table of Contents

Page

I. Introduction B-1

A. Cotton Scouting in Arkansas B-2
B. Pest Management in North Carolina B-3

II. Scouting Characteristics B-8

A. Arkansas Scouting B-8
B. North Carolina Scouting B-13

III. Measures of Program Effects B-22

A. Benefit Measures of Pest Management B-22
  1. Arkansas B-22
  2. North Carolina B-32

B. Program and Farm Costs B-35
  1. Arkansas B-35
  2. North Carolina B-42

C. Environmental Impact B-46
  1. Arkansas B-46
  2. North Carolina B-50

IV. Summary and Projections B-54

A. Constraints on Expansion of Cotton Pest Management B-54

B. Summary of Future Possibilities B-56

References B-58

List of Tables

Page

1.1 - Use of Scouts in Arkansas Cotton Production B-4
1.2 - Acreage in Pest Management in North Carolina Cotton Production B-5

2.1 - Scout Load Characteristics - Arkansas 1959-1973 B-10
2.2 - Grower Pest Management Training - Arkansas B-12
2.3 - North Carolina Pest Management Group Characteristics 74, 73, 72 B-14,15,16

3.1 - Yields Per Harvested Acreage Selected Counties in Arkansas B-24
3.2 - Scouts and Percent of Acreage Scouted, Selected Counties - Arkansas B-25
3.3 - Insect Infestation Levels in Arkansas Cotton B-26
3.4 - Percent of Arkansas Fields Treated by Week B-30
3.5 - County Yield Per Acre Regression Coefficients North Carolina, 1957 to 1966 B-36
3.6 - Estimates of Direct Scouting Cost - Arkansas 1960-1974 B-39
3.7 - Arkansas Cotton Pest Management Costs B-41
3.8 - Costs to Growers Per Acre Scouted by Groups, North Carolina B-43
3.9 - North Carolina Grower Cooperative Costs Per Application B-44
3.10 - North Carolina Public and Private Program Costs B-45
3.11 - Number of Insecticide Applications, Arkansas 1969 B-47
3.12 - Insecticide Use Estimates-County Agents, Arkansas B-48
3.13 - Insecticide Expenditures Per Cotton Acre Harvested B-49
3.14 - Number of Insecticide Applications, North Carolina, 1969 B-51
3.15 - Insecticide Use by Cooperative and Commercial Groups, North Carolina, 1972-1974 B-52

List of Figures

Page

1 - Cotton Scouts in Arkansas, 1971 B-9

2 - Cotton Yield and Percent of Acreage Scouted, Arkansas Counties, 1967 B-27

3 - Percentage of County Acreage in Scouting Programs B-37

4 - Percentage of County Acreage in Scouting Programs B-38

I. Introduction

An entomologist brought some cross-sectional survey data on pest infestation levels, insecticide use and other field observations to an economist for evaluation. The economist found that there was a strong positive correlation between infestation intensity and amount of insecticides used and concluded that insecticides tend to increase target insect populations. This was in the 1940's; yet it reminds us of the complexity of quantitative evaluation of economic and environmental aspects of pest control activities.

One principle of integrated pest control is to utilize chemical pesticides only when and where pest populations exceed the infestation level at which the value of the damage prevented is equal to the control costs. Use of paid scouts to inspect cotton fields to determine when this level is reached has a long history in Arkansas. In North Carolina, paid scouts are much more recent, but the proportion of state cotton acreage scouted has increased rapidly in recent years. It will be instructive to compare the advance of scouting under the widely divergent farm size, field size and crop diversification structures of the two states.

There are many other resources besides paid scouts which assist in integrated pest control. Some of these such as state-wide weather information and insecticide treatment recommendations are typically provided by public agencies, since they have the usual characteristics of public goods. Others such as pest-resistant crop varieties and selective pesticides are sold by agribusiness firms. Private pest control specialists who sell "advice" and scouting are also present in the study areas. A final resource is the stock of knowledge which growers and farm managers have on pest control. The costs and contributions of each of these resources are difficult to measure. Where available, data on all of these resources will be provided. The emphasis will be on the labor component - scouts and farmer training.

A. Cotton Scouting in Arkansas

The scouting effort in Arkansas is primarily carried out by scouts hired and supervised by the cooperative extension service. Wages for these scouts and their travel are paid by growers through fees based on acreage of cotton placed in the scouting program. The extension program started in 1950 with three scouts and has increased to a high of 184 in 1972. There were 155 extension scouts and 5 independent scouts in 1974. Over 1200 persons have been trained as paid scouts in the last 25 years.

Independent scouts are those who are not hired and supervised by county agents. They contract for services directly with the farmers. Most of them have received training at extension scouting schools and most have been an extension scout for one or more years. Usually they cooperate closely with the extension scouting effort. During the mid-1950's many independent scouts were scouting cotton in the central Delta counties of Arkansas. They worked for several agricultural chemical firms, but were trained and recruited by the state survey entomologist. In general the independent scouts provide similar service to growers. Fees currently range from $1.25 to $1.50 per acre depending upon field size and travel distance.

Extension scouts operate by checking each 40 acre or smaller field at least once per week according to the guidelines of cooperative extension leaflet 52 (revised). Reports are given directly to the grower using a standardized form. Records are also mailed to the state extension entomologist and compiled by county agents at weekly scout meetings. Reports to growers indicate whether each of six pest species (boll weevil, bollworm, aphids, mites, plant bugs and white fly) are above treatment thresholds. Growers utilizing their training and information in leaflet 52 make insecticide use and other control decisions.

Scouting ideally permits treatment at optimal times to maximize grower profits. This includes preserving beneficial insects and knowing the susceptibility of the cotton plant. Regular reports of plant development in terms of node counting and square counting (number of row feet necessary to count a specified number of squares) can assist in pest control and other agronomic decisions (see Arkansas Extension Leaflet 479). Treatment thresholds are based on damaged squares per row foot which changes as squaring rate changes. Squaring rate through the season increases at an increasing then a decreasing rate (see Leaflet 52).

Table 1.1 shows the history of the use of scouts in Arkansas. Extension hired and supervised scouts increased rapidly during the 1950's and again in the late 1960's. The increase in the 1950's involved many counties initiating an extension scouting program. Note that with the declining cotton acreage grown in the 1960's, that there was an increase in percent of state acreage scounted from about 12 percent in 1960 to about 20 percent in 1970. Data on acres, fields, and farms scouted is also presented if available.

B. Pest Management in North Carolina

Eleven farmer-directed pest control cooperatives and three commercial firms are actively involved in cotton pest control in 1974 in North Carolina. Table 1.2 shows the acreages in these programs for the last several years for which data is available. The acreage has grown from a few thousand in 1967 to about 76,000 in 1974.

Table 1.1. Use of Scouts in Arkansas Cotton Production

Scout Numbers					Area Scouted				
Year	Total Scouts[a]	Extension Scouts[b]	Independent Scouts[c]	Scout Supervisors	Counties[c]	(000) acres[c]	fields[c]	farms[c]	Percent of state acreage[a]
1949	2	0	2	0	2				
1950	10	3	7	0	5				
1951	22	21	1	0	12				
1952	31	30	1	0	12				
1953	34	32	2	0	11				
1954	42	39	3	1	17				
1955	52	42	10	1	15				
1956	81	56	25	1	18				
1957	86	68	18	1	20				
1958	81	64	17	1	15	100			
1959	109	92	17	1	21	150	6500	1100	11.5
1960	127	120	7	1	24	170.5	7025		12.9
1961	130	122		1	25	165.9	7174	932	12.2
1962	134	138		1	26		6342		
1963	127	115		1	30		6550		
1964	129	123		1	26		7193		
1965	127	123		1	27		7645		
1966	108	100		1	26		5781		
1967	98	95		1	22		4363		
1968	132	127		1	24	176	6207		
1969	139	123		1	25	180	6414		
1970	157	147		1	26	207.5	6919	881	19.4
1971	168	166		1	24	232.6	7296	941	20.4
1972	184	184		3	26	255.3	6943	791	18.1
1973	149	144	5	6	23[e]	204.0[e]	5726[e]	892[e]	20.4[e]
1974	160	155	5	7	25[e]	217.0[e]			

a - from the files of W. P. Boyer, Survey Entomologist, Fayetteville, Arkansas.

b - from W. P. Boyer's file 1949-1959, pay records, cooperative extension service, 1960-1974 for all scouts insured under state insurance program.

c - records of W. P. Boyer - all blanks are unavailable data.

d - based on scout records of W. P. Boyer and statistical reporting service for state acreage harvested.

e - extension scouting only.

Table 1.2. Acreage in Pest Management in North Carolina Cotton Production

	1967	1968	1969	1970	1971	1972	1973	1974
Cooperatives					Number of Acres			
1			1796*	3465	3998	6046	6391	6215
2					N/A*	3000	4900	6015
3				1200*	N/A	3800	3800	3800
4				1800*	N/A	3066	2550	4000
5						2300*	2600	2100
6						2200*	2700	4200
7			N/A*	N/A	N/A	4600	4400	4300
8						1202*	1655	3000
9						4200*	4800	7100
10						1000*	2100	2967
11	1700*	N/A	N/A	N/A	N/A	3780	2520	1800
					TOTAL	34,994	38,416	45,497
					TOTAL SCOUTED	31,994	33,516	39,482
Commerical Operations								
1						0	7,800*	26,700
2		*				2,500	2,500	2,500
3[a]						1,400	1,400	1,400
					TOTAL	3,900	11,700	30,600
					STATE TOTAL	38,894	50,116	76,097
					State Planted Acreage	210,000	182,000	180,000
Percent of state cotton acreage in an organized program						18.52	27.54	42.28
Percent of state acreage scouted[b]						17.09	24.84	38.93

---

* - founding date

N/A - data not available

a - founding date not available

b - excludes acreage of cooperative No. 2 which is not scouted as compared with percent of state cotton acreage in an organized program.

It is doubtful whether all 14 of these groups are following integrated pest management. (Details on the operation of each group are presented in a later section). Cooperative group No. 2 which has no scouts, and commercial groups 1 and 2 which sell insecticides and flying service, as well as scouting services, probably are the most questionable. Yet, it will be necessary to determine if the commercial groups are not providing valuable scouting services. It will be instructive to compare yields and insecticide use between various groups which employ different degrees of scouting and management.

The cooperative groups, often known as "spray groups", serve several pest control functions. Scouting, aerial applicator services, insecticide purchase, bookkeeping, insect trap monitoring, and insecticide use decisions are performed by some but not all cooperatives. In 1973, the group consisted of 20 to 70 farmers in a locality with several member directors. Some groups have a farmer(s) who is manager and decision maker, other groups have a manager who has on-the-job training in entomology. These decision makers decide when and with what material to treat all acreage in the spray group. Thus, farmer subscribers transfer pest treatment rights on their cotton acreage to the cooperative. A contract is signed by each grower which indicates his payments per acre per season and the authority for the cooperative to scout and apply insecticides on his own acreage or requesting reasonable changes for his particular farm.

Benefits of participation in cooperatives which are cited by directors and warrant evaluation are: better timing of insecticide treatments, lower cost and more reliable supply of insecticides; more timely plane services; area-wide weevil suppression through coordinated diapause and "in-season" control; less insecticide use from selective treatment of fields; reduced scattering of used insecticide containers.

The next section will give a listing and discussion of the scouting programs by location, section III-A will evaluate yield effects of the scouting programs, section III-B concentrate on program costs, and section III-C evaluates environmental effects of the pest management programs. Section IV is a discussion of expansion constraints and a summary.

II. Scouting Characteristics

A. Arkansas Scouting

The major users of cotton scouts in Arkansas have been the farmers in the southern Delta where boll weevil was a persistent pest. However, in recent years there has been an increase in cotton scouting in northern Delta counties such as Mississippi, Poinsett and St. Francis. Figure 1 shows the location of scouts in 1971.

As will be seen in a later section on scouting effectiveness the major explanatory factor for increases in scouting has been presence of uncontrolled pests in previous years. Interest and leadership by county agents such as in Jefferson and Jackson counties also contributed to growth in scouted acreage. For example, when the Jackson agent left in the early 60's the program sharply declined.

The size of farms and fields and the gradual increase in farm size has changed scout working loads through time. Table 2.1 gives state acres per scout, fields per scout and acres per farm over the period from 1959 to 1973. Acres per scout has increased from about 1350 acres in 1959-61 to 1400 acres in 1961-71. Field numbers per scout have declined from 55 to 45 during this period.

Scout work loads probably have remained constant over time. Most scout supervisors and county extension agents feel that fields per scout is a better indicator of work load than acres per scout since number of field checks and grower reports is closely linked to field numbers. Therefore, there may have been a slight decline in workload if time per field is constant. Time per field probably has risen since number of species counted has increased (white fly observations began in 1972), cotton growth monitoring began in 1968, and scouts have helped monitor sugar lines in the last few years.

168 Scouts in 24 Counties

FIGURE 1. COTTON SCOUTS IN ARKANSAS - 1971

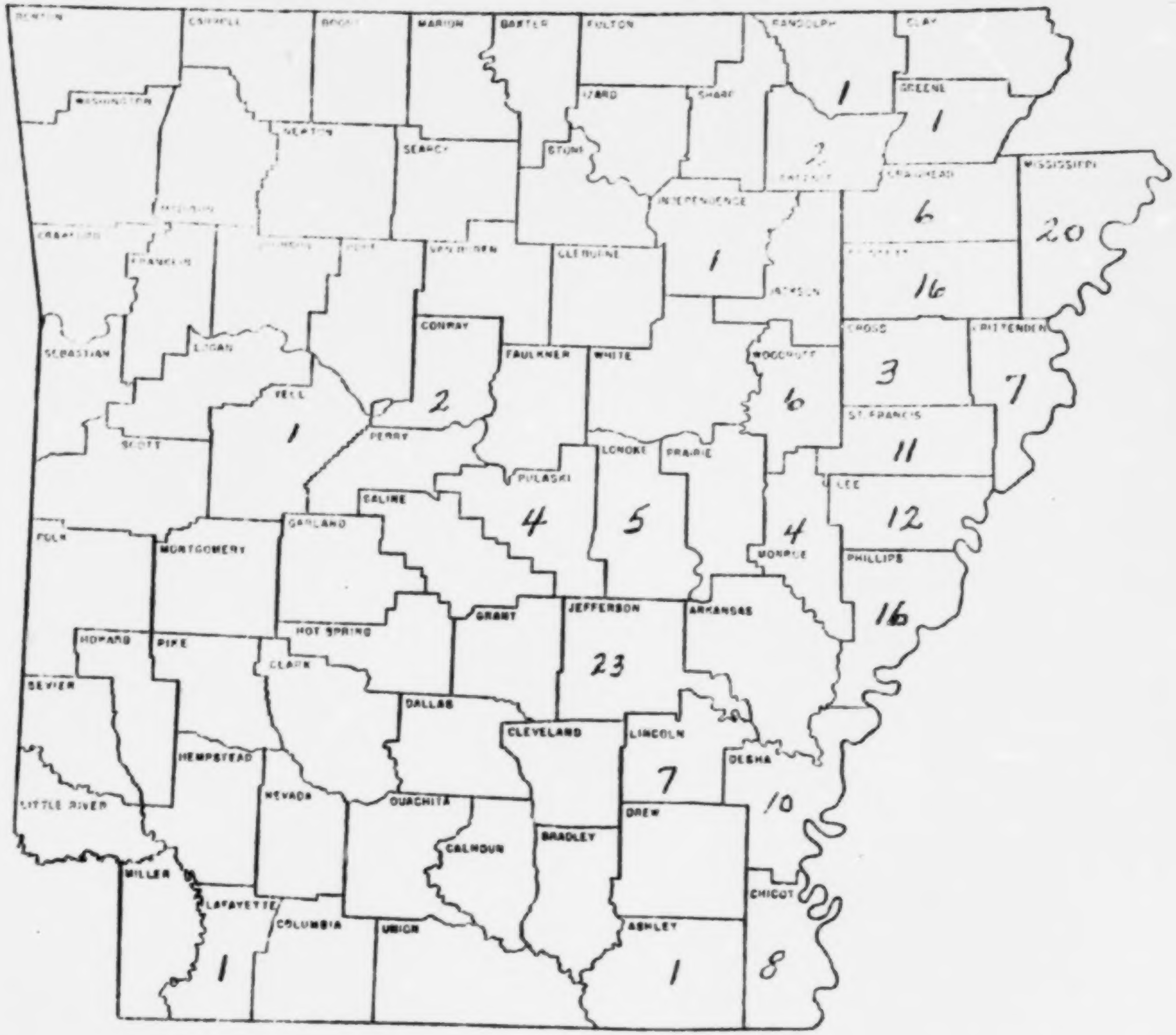
BENTON
CARROLL
BOONE
MARION
BAXTER
FULTON
RANDOLPH
1
CLAY
GREENE
1
WASHINGTON
NEWTON
SEARCY
STONE
IZARD
SHARP
2
LAWRENCE
CRAIGHEAD
6
MISSISSIPPI
20
MADISON
CRAWFORD
FRANKLIN
JOHNSON
POPE
VAN BUREN
CLEBURNE
INDEPENDENCE
1
JACKSON
POINSETT
16
SEBASTIAN
LOGAN
CONWAY
2
FAULKNER
WHITE
WOODRUFF
6
CROSS
3
CRITTENDEN
7
YELL
1
SCOTT
PERRY
ST FRANCIS
11
LONOKE
PRAIRIE
PULASKI
4
5
LEE
12
SALINE
MONROE
4
POLK
MONTGOMERY
GARLAND
PHILLIPS
16
GRANT
JEFFERSON
23
ARKANSAS
HOWARD
PIKE
HOT SPRING
CLARK
SEVIER
DALLAS
CLEVELAND
LINCOLN
7
DESHA
10
HEMPSTEAD
LITTLE RIVER
NEVADA
OUACHITA
CALHOUN
BRADLEY
DREW
MILLER
LAFAYETTE
COLUMBIA
UNION
CHICOT
1
ASHLEY
1
8

Table 2.1. Scout Load Characteristics - Arkansas 1959-1973[a]

Year	Acres Per Scout	Fields Per Scout	Acres Per Field	Scouted Acres Per Farm	Average Acres All Cotton Farms[b]
1959	1376	60		136	37.2
1960	1343	55		178	
1961	1276	55			
1962		47			
1963		52			
1964		56			56.9
1965		60			
1966		53			
1967		44.5			
1968	1333	47			
1969	1295	46			71.6
1970	1397*	45	29.9	236	
1971	1399*	45*		247 323	
1972	1430*	43*		229	
1973	1417	40			
MEAN	1363	49.9			

* - adjusted for part time scouts
a - from files of W. P. Boyer and weekly insect letter for fields scouted
b - census of agriculture

The size of farms subscribing to extension scouting services seems to be much larger than the average of all Arkansas cotton farms. As shown in Table 2.1, cotton acres per farm on scouted farms was about 150 acres in 1959-1961 and 250 acres for 1970-1973, while similar figures for all farms were 37 to 72. Data is not available on the distribution of scouted farms by size, but the following figures for field size are:

	< 10 acres	11-25 acres	26-40 acres	> 41 acres
1972	890	2075	1620	1735
1973	909	1870	1350	1417

Detailed records of this type are available from computerized records. However, no analysis of the effect of field size on scouting costs has been attempted.

The monitoring of traps and sugar lines is a small but increasing part of scouting responsibilities. For example in 1973 scouts monitored 8 bollworm-budworm light traps, 13 sugar lines and at least 90 Legget traps for weevils. Scout supervisors and county agents also assist in disseminating the information from these warning devices.

An important part of cotton scouting and integrated pest control in Arkansas is conducted by farm operators (and families). It is estimated by county agents that 40-50 percent of the farmers scout their own fields. With extension scouts, private scouts and farmer scouting, as much as 80 percent of cotton may be scouted. This is difficult to verify, but the amount of grower pest management training for the past twenty-five years is partially shown in Table 2.2. Scouting schools in the field for 2 to 6 thousand growers per year was common. Radio, TV, and insect newsletter are widely used. This has undoubtedly built a stock of knowledge which has helped Arkansas growers use paid scouts' insect counts or perform their own insect scouting.

Table 2.2. Grower Pest Management Training - Arkansas[a]

Year	Scouting Schools	No. of farmers	Radio Tapes	TV Programs	Regular County Insect Letter	No. of Counties Pest Control Demonstration
1949	33	310				
1958	427	6,474				
1959	422	7,248				
1960	429	8.303				
1961	265	2,725				
1962	72	645				
1963	75	991			15	
1964	238	1,570	81	26	13	
1965			65	26	23	
1966			48	30	15	6
1967						5
1968						3
1973						

a - from "Cotton Insects in Arkansas" 1959-1973

B. North Carolina Scouting

Fourteen cooperative or commercial pest management organizations were identified to be operating in North Carolina in 1974. Each was contacted by personal interview or telephone to obtain operating data for the period 1972 to 1974. This data is summarized in Tables 1.2 and 2.3.

The major change has been the increase in total acres scouted. Deleting cooperative No. 2, which does not employ scouts, the percent of planted acreage scouted by organized groups was 17 percent in 1972, about 25 percent in 1973 and about 39 percent in 1974 (See Table 1.2).

A major change which took place between 1973 and 1974 was the increase in scouting by smaller farmers. The number of farmer subscribers in the 11 cooperatives rose from 401 to 547 and the average farm size fell from 91 acres in 1973 to 82 acres in 1974. Note that the commercial firms serve much larger farms than the cooperatives (about twice as many cotton acres in 1974). Field size is also down between 1972 and 1974 in several groups.

The scout work load is fewer acres, but more fields, than in Arkansas. Acres per scout is about 1050-1100 for cooperative scouts and about 1400-1600 for commercial scouts. Fields per scout was about 91-96 per scout until 1974 when it rose sharply to about 121. The workload appears particularly high in cooperative 1 in all three years and in group No. 5 in 1973. Six of the cooperatives have hired more scouts as field size and farm size has decreased.

The decision making authority in the cotton pest control organizations varies considerably. Several of the groups are making progress towards integrated pest management. The use of scouting has allowed some early season reduction in chemical use. Those groups with active management treat fields selectively at least for part of the susceptible, fruiting season. Several of the groups have attempted organized boll weevil diapause control which has allowed delay of initiation of treatments in the subsequent year to as

Table 2.3. Pest Management Group Characteristics - North Carolina, 1974

Group	Acreage	No. Farmers	No. Fields	No. Scouts	Acres/ Scout	Acres/ Field	Acres/ Farmer	Manager Bookkeeper	Fields per Scout
Cooperative Groups									
1	7000[a]	57	720	4	1750	9.7	122.8		
2	6015	60-65		0			92-100	1	
3	3800	40	400	4	950	9.5	95	1	
4	4000	69	522	4	1000	7.7	60	1	
5	2100	18	350	2	1050	6	116.7	1	
6	4200	42		4	1050		100	1	
7	4300	46	287	4	1075	15.0	93.5		
8	3000	38	400	3	1000	7.5	78.9	1	
9	7100	115	757	7	1014	9.4	61.7	2[c]	
10	2967	58	300	3	989	9.9	51.1	1	
11	2000	2	74	2[b]	1000	27	1000		
	Totals	547		37					
Mean					1088	8.6	87.7[d]		126
Commerical Operations									
1	26,700	93-96		19	1405		278-287	3	
2	2,500	20		1	2500		125		
3	1,400	8		1	1400		175		
	Totals	122		21					
	Mean				1368		194		

a - 700 in Virginia
b - 3 days per week
c - also receives extensive help from one USDA employee
d - without group 11 which only has two growers

Table 2.3. Pest Management Group Characteristics - North Carolina, 1973

Group	Acreage	No. Farmers	No. Fields	No. Scouts	Acres/ Scout	Acres/ Field	Acres/ Farmer	Manager Bookkeeper	Fields per Scout
Cooperative Groups									
1	6591[a]	42	637	5	1318.2	10.35	156.9		
2	4900	52		0			94.2		
3	3200	33[d]		3[d]					
4	2550	39	346	3	850	7.40	65.4	1	
5	2600	20		2	1300		130	0	
6	2700	27		3[c]	900		100		
7	4400	43	291	4	1100	15.1	102.3		
8	1655	29		2	828		57.1	0	
9	4800	70	512	5	960	9.4	68.6		
10	2100	36	195	2	1050	10.8	58.3	1	
11	2800	10	140	3	933	20	200		
	Totals	401		37					
	Mean				1027	12.2	103		84
Commercial Operations									
1	7800	30		8	975		260		
2	2500	20		1	2500		125		
3	1400[b]	8		1	1400		175		
	Totals	58		10					
	Mean				1625		187		

a - 200 in Virginia
b - 700 in South Carolina
c - part time
d - estimated

Table 2.3. Pest Management Group Characteristics - North Carolina, 1972

Group	Acreage	No. Farmers	No. Fields	No. Scouts	Acres/ Scout	Acres/ Field	Acres/ Farmer	Manager Bookkeeper	Fields per Scout
Cooperative Groups									
1	6246	45	450	4	1562	13.9	138.8		
2	3000			0					
3	3800								
4	3066	48	437	6	511	7.0	63.9		
5	2300	20		2	1150		115	0	
6	2200								
7	4600			4	1150			1	
8	1202								
9	4200	70-80	400	5	826	10.3	52-59		
10	1000								
11	4200	30	235	3	1400	17.4	140		
Mean					1100	12.1	103		91
Commercial Operations									
1									
2	2500								
3	1400								

late as August 1st (compared with the usual June 15th starting date). Some groups use scouts and light traps to determine when to switch insecticide material for bollworms.

Some growers participate in "spraying group" cooperatives for other reasons. Group number 9 had 5-6 members join in 1974 when the groups found that they would have difficulty purchasing cotton insecticides at any price independently. The most often expressed reason for joining a spray cooperative was to have a readily available aerial applicator. This appears to be more of a problem with the increase in relative importance of the bollworm which can cause substantial damage in a short amount of time such as in August 1973. (Pest infestation levels are discussed in section III-A). All of the cotton pest control cooperatives are in the northern part of the state where cotton is a secondary crop to peanuts, tobacco or corn on many farms. Growers cannot specialize in pest management on cotton as an individual.

Spray cooperative managers and USDA-Extension personnel help monitor traps for measuring weevil and bollworm populations. In 1974 a total of 770 weevil traps were used in the four county area in which the first 10 of the 11 groups are located. These traps help monitor progress of the weevil diapause program and timing of the bollworm flights. Summaries are distributed by radio broadcasts and newsletters.

Group No. 1

This group is a cooperative in which the decisions are made by the chairman of the group. Fields are not sprayed on an individual basis, but if less than 10% of fields need spraying more are sprayed. The chairman makes his spraying and type of chemical decisions on the basis of the scouting reports and the light trap figures from the 3 light traps in his county. They have a flying service under contract with a guarantee of at least 9 applications in 1974. The chairman feels that the group has become too large to be run by volunteer labor but the cooperative has so far been unable to find an acceptable cooperative manager. He recognizes that they have too few scouts. Their diapause control consists of Guthion added to the defoliant.

Group No. 2

This is a cooperative spraying group that does not employ scouts. They had scouts their first year (1971) and apparently had a bad experience with them. The chairman thinks that they should have scouts. He does monitor one light trap. They do not have a professional manager but do employ a bookkeeper.

Group No. 3

This is a cooperative spray group in which spraying decisions are made by the board of directors using scouting information and the information from a light trap they service. Their diapause control consists of Guthion added to the defoliant.

Group No. 4

This is a cooperative group in which the spraying decisions are made weekly by a committee of three members. They use scouting and light trap information. This group received considerable assistance during 1972 through 1974 from the USDA-Extension Cotton Insect Pest Management Program. They expect to apply 9 to 10 applications this year but could apply more if the grower needs to. The chairman of the group thinks that the diapause treatment in 1973 enabled them to avoid two weeks of spraying in 1974.

Group No. 5

This is a small group which has remained stable in size in contrast to most of the other groups which have shown significant growth. Spraying decisions are made by the chairman and the manager using scouting and light trap reports. They applied diapause control to part of their acreage in 1973 and plan to apply insecticide to their defoliant to all their acreage in 1974.

Group No. 6

In this program decisions are made by a committee. They do not spray fields selectively, but did pause after their first sprayings for boll weevils in 1974. They have contracted for 10 sprayings but individual growers can opt out of the first two sprayings if they wish to take two extra sprayings at the end of the season.

They use scouts and receive moth counts from the three light traps in their county. They did not practice any diapause control in 1973.

Group No. 7

This group is one of the oldest spray cooperatives operating in the state. In 1974 they employed a professional manager, but the board of directors makes the final decisions on spraying.

They sprayed fields selectively, upon grower request, until 85% of the fields were being sprayed and then began a routine of spraying all acreage. In 1974 they contracted for 10 sprayings.

The scouts were released early in 1974 as the manager felt that they were not doing a worthwhile job any longer. Only four farmers used diapause control in 1973, but the manager considers that it did make a difference in early boll weevil numbers for those farmers.

Group No. 8

This is one of the smaller groups. They contract for 10 applications, but the grower can apply two more if he wishes. This year they sprayed selectively upon grower request the first time and then went to a routine schedule on all fields.

Group No. 9

This is one of the largest groups. In 1974 it may be the closet to an integrated pest management program. They are charging the farmer more than any other group, but in return have a more complete managerial organization and more late season and diapause control. The scouts are supervised both by a supervisor and by a U.S.D.A. entomologist who is assisting the group quite extensively. In 1974, this group did more selective spraying than any other and did not go to a full spray schedule until August 1. This will result in refunds to growers which will lower costs. Their county had a nearly complete diapause program in 1973 on over 60 percent of the county cotton acreage.

Group No. 10

This group employs a manager who makes the spraying decisions. He considers that scouts are needed even when everything is being sprayed regularly in order to catch special problems. This group does not plan any diapause control in 1974 because of the acreage in their area which is not in any program and which will not have diapause control applied.

Group No. 11

This group was one of the first in the state to be formed. It operates under the direction of one grower, although several growers are included. It has been reduced in size the last two years because the grower who formed it feels that other scouting is available and that it was absorbing too much of his time. He has therefore reduced the size of the group to his families' farms and their neighbors. He doesn't think that scouting saves much money, but that it increases the probability of a profitable yield. However, this year by August 1 he had not sprayed two-thirds of his acreage at all. This was due to a diapause program of three sprayings on part of the acreage the year before and then selectively spraying during July.

Commercial Organization, No. 1

This is a farm service company that has expanded into scouting the last two years. They offer a variety of services to the farmer ranging from scouting to selling chemicals and application services. In common with most of the groups they had no farmers leave the scouting program between 1973 and 1974.

Commercial Organization, No. 2

This is a commercial organization that has scouted for seven or eight years. They also apply the chemicals for most of the growers.

Commercial Organization, No. 3

This is a single private scout who has scouted fields and given treatment recommendations to larger growers for a number of years.

III. Measures of Program Effects

A. Benefit Measures of Pest Management

Several benefit measures of pest management can be employed depending upon data availability. The main problem is standardizing for other factors besides pest management which influences yields or profits. The measures proposed are:

(i) the effect of percent of acreage scouted on yields (Arkansas counties).

(ii) effect of scouting on early season insecticide treatments (Arkansas).

(iii) effect of infestation records on marginal productivities of insecticides (Arkansas).

(iv) comparison of yields of cotton farms in a cooperative pest group with farmers not in the group adjusting for historical differences in yield (2 groups in North Carolina).

(v) relationship between percent acreage scouted and deviation from predicted yield from a cross-section, time-series multiple regression model (North Carolina counties, 1972-73).

A-1 Benefit Measures of Cotton Pest Management in Arkansas

It is impractical to try to design an experiment to compare those farmers in Arkansas who use integrated pest management and those who do not. Most all of them probably apply some pest management principles. Many growers in all cotton producing counties in Arkansas have received training as indicated in Table 2.3. Yet, some counties have had an extension scouting program for a shorter period of time, or have a smaller proportion of their cotton acreage scouted.

(i) The effect of percent of acreage scouted on yields: data on county yields, number of scouts, and scouted acreage were compiled for eight counties. This data is shown in Tables 3.1 and 3.2. The counties were selected to get a divergence in average pest level and percent of acreage scouted. C. Lincoln, Entomologist, University of Arkansas, characterized the counties as to soil fertility and bollweevil pest hazard as of 1960 (unpublished report) as given in Table 3.1.

Adoption of paid extension scouts was rapid in Jefferson, Desha, Phillips and Lonoke counties following substantial yield reduction from weevils in 1949 and 1950. Woodruff, the other county with a high weevil threat, did not adopt paid scouts during the 1950's probably because of smaller growers and the fact that the small acreage in the county did not justify a county agent's time. On the other hand, Mississippi, Craighead, Woodruff, and St. Francis did not accept extension scouting to a large extent until 1966-1970 following the heavy boll weevil and bollworm infestations of 1966 and 1967 in these more northern parts of the state. Table 3.3 gives several indices of the relative level of pest infestation for the state. Columns 1 and 4 indicate background extensiveness of worm and weevil threats, while columns 2, 3 and 5 indicate the extent of damage to the crop.

The relationship between harvested yield and degree of scouting is confounded by other forces in most years. A more complete yield model which includes planting date, rainfall, and effects of boll rot and soil fertility is needed. However, for severe pest seasons such as 1967 and 1970 there does appear to be some yield advantage for those counties with higher levels of scouted acreage. Figure 2 shows cotton yields and acreage scouted for

Table 3.1. Yields Per Harvested Acre/Selected Counties in Arkansas

Year	Pest Conditions	Conditions I		Conditions II		Conditions III		Conditions IV	Conditions V
		Phillips	Desha	Jeff.	Lonoke	Miss.	Craig.	Woodruff	St. Francis
1948	BWE*	485	467	485		483	432		
1949	BWE	305	229	313		443	421		
1950		317	348	355	294	352	350	313	423
1951		322	211	232	262	347	301	354	276
1952		370	376	344	264	408	366	284	308
1953		335	381	421	349	406	388	337	372
1954		472	445	389	303	457	358	297	445
1955	BWE	623	651	621	508	621	431	545	638
1956		548	566	565	483	565	480	467	597
1957		445	390	527	489	354	334	441	470
1958		399	438	584	536	363	451	467	438
1959		568	630	533	517	615	593	577	607
1960		495	541	559	475	494	455	484	476
1961		552	566	588	523	487	529	519	516
1962		545	444	475	466	559	501	499	574
1963	BW	679	584	599	503	647	511	604	601
1964		751	626	634	567	615	620	590	647
1965		607	584	670	599	605	576	546	506
1966	BW BWE	569	585	488	480	355	273	340	378
1967	BWE BW	457	513	505	391	249	243	244	269
1968		526	633	643	503	514	465	423	398
1969	BW	515	592	668	597	552	499	459	410
1970	BW BWE	533	576	621	589	455	419	333	427
1971	BWE	552	551	636	709	520	524	420	449
1972		546	536	637	574	534	463	368	403
1973		570	643	638	648	377	411	508	487

Conditions
I - High pest conditions, fertile soil
II - High pest conditions, medium soil
III - Low pest conditions, fertile soil
IV - High pest conditions, medium soil
V - Low pest conditions, medium soil

*BWE - Boll weevil present or present in damaging levels in many areas of the state
BW - Boll worm present or present in damaging numbers

Table 3.2. Scouts and Percent of Acreage Scouted - Selected Counties

	Counties							
Year	Phillips	Desha	Jeff.	Lonoke	Miss.	Craighead	Woodruff	St. Francis
	Cotton Scout Numbers							
1950	1	0	0	0	0	0	0	0
1951	1	0	2	1	0	1	0	0
1952	1	1	6	1	2	2	0	0
1953	1	1	10	2	0	1	0	0
1954	1	5	9	2	0	1	0	1
1955	3	5	11	2	0	1	0	3
1956	5	5	11	6	0	3	0	9
1957	5	6	13	6	3	2	1	3
1958	2	6	15	6	5	2	0	1
1959	10	7	21	7	5	2	0	1
1960	11	8	22	8	8	2	0	0
1961	8	8	20	14	5	5	2	0
1962	8	9	21	13	5	5	0	0
1963	9	8	19	7	6	4	2	1
1964	11	11	19	7	6	6	2	0
1965	11	10	18	6	10	5	4	1
1966	9	8	18	5	8	4	4	2
1967	7	9	17	6	7	3	4	1
1968	8	11	20	6	11	6	4	2
1969	8	11	21	6	16	7	5	2
1970	10	10	21	4	17	6	6	8
1971	16	10	23	5	20	6	6	11
1972	19	6	27	6	24	8	7	16
1973	10	8	20	5	16	6	7	12
	Percent of Acreage Scouted							
1950	1.7	0	0	0	0	0	0	0
1951								
1952	1.2	2.1	6.5	1.8	1.0	2.5	0	0
1953								
1954	1.4	12.8	15.9	4.3	0	1.4	0	1.7
1955								
1956	8.3	15.4	21.3	15.6	0	5.1	0	18.9
1957								
1958	4.0	26.1	32.6	19.2	4.1	4.3	0	2.7
1959								
1960	19.5	25.7	38.3	21.5	5.5	3.1	0	0
1961								
1962	12.3	26.5	38.5	33.8	3.4	6.3	0	0
1963								
1964	14.6	35.4	38.1	20.8	4.5	10.3	8.2	0
1965								
1966	22.2	35.5	45.8	20.8	8.0	8.3	22.6	6.3
1967	18.5	46.6	49.8	28.0	9.0	7.9	20.6	3.9
1968	15.5	40.8	47.6	22.8	9.2	12.3	20.4	6.0
1969	15.9	39.0	48.2	23.7	13.1	12.9	23.2	5.5
1970	20.8	36.7	47.6	14.6	14.6	11.2	27.8	25.4
1971	29.2	32.0	45.5	17.1	15.9	10.0	27.8	30.4
1972	27.2	12.8	41.1	16.7	16.2	11.1	27.8	38.9
1973	19.2	24.2	34.4	15.9	16.3	12.5	35.5	41.9

Table 3.3. Insect Infestation Levels in Arkansas Cotton

Year	Bollworms			Bollweevils	
	% field[a] infested	% fields with >5% square damage[a]	% weeks with ≥ 5%SD	% field infested[a]	% fields above threshold[a]
	(1)	(2)	(3)	(4)	(5)
1958	49			60	
1959	46			72	
1960	51			71	
1961	42			64	
1962	51		7.8	77	
1963	57	16.9[b]	18.5		6.0
1964	49	10.5[b]	11.3		2.8
1965	42	5.5[b]	6.7		10.8
1966	48	4.5	7.9	57	14.0
1967	57	15.0	23.6	62	28.0
1968	45	5.0	9.1	53	11.0
1969	57	12.0	17.7	51	
1970	66	20.0	24.8	44	12.0
1971	51	12.0		54	14.0
1972	71	3.6		60	6.4
1973	72	2.0		54	2.0
Mean	53.4	9.7	14.2	59.9	10.7

a - season average over 11 weeks, from "Cotton Insects in Arkansas, 1958-1973"

b - greater than 4 percent square damage

c - from Lincoln, Charles and W. P. Boyer, "Bollworm Outbreaks on Cotton in Arkansas, 1962-1970", Mimo Series No. 211, March 1973, average of forty locations, with approximately 100 fields per location

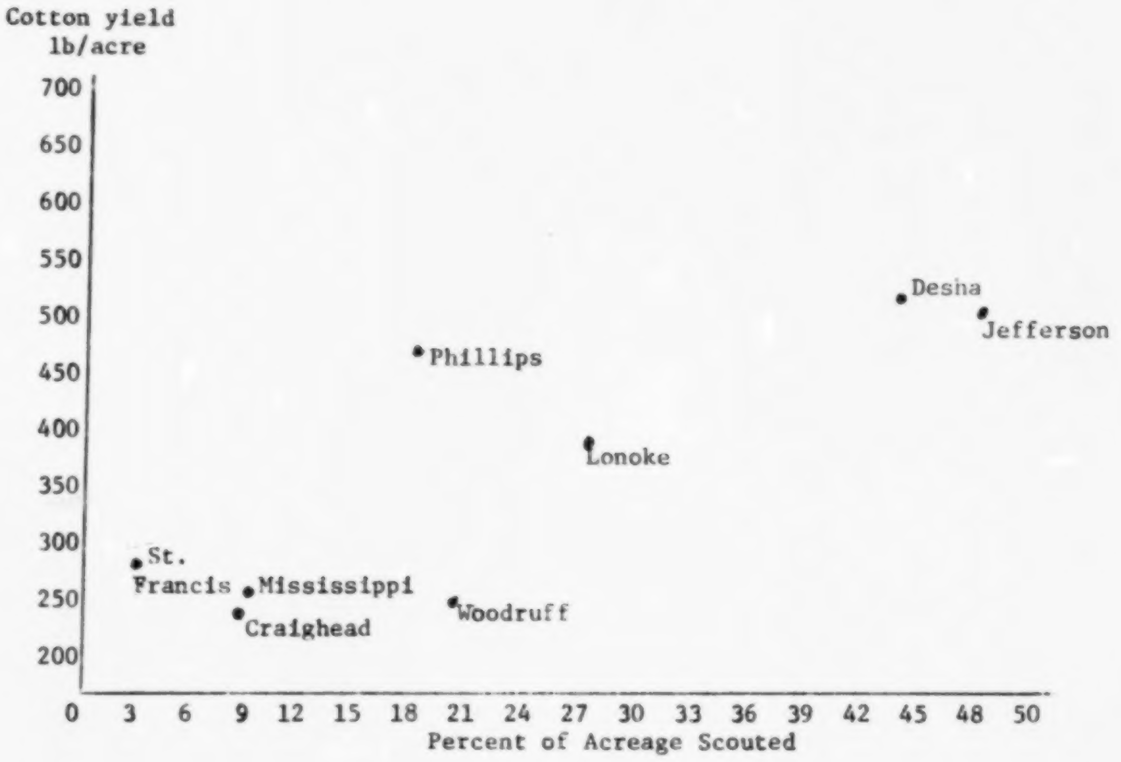

Figure 2. Cotton Yield and Percent of Acreage Scouted, Arkansas Counties - 1967

eight counties. Noting that Phillips has high soil fertility and Woodruff has low fertility, there appears to be an increase in yields from scouting. A more complete model of scouting adoption and yields is needed to be certain, because the year shown was an expectionally difficult pest year.

(ii) Effect of scouting on early season insecticide treatments: One view of the effect of weekly pest infestation information on pest control decisions is its influence on early season insecticide treatment. This follows from the view that once insecticide treatments begin the natural enemies will be destroyed so that "regular" treatments at 5 to 7 day intervals will be profitable. Thus, the effect of scouting on delaying first treatment is a benefit indicator in terms of reducing insecticide use while holding yields constant.

Three pieces of information bear on the effect of scouting on early season treatments. The first can be found in Arkansas Experiment Station Bulletin 682 by Tugwell and Waddle where they show that on experimental plots in Southeastern Arkansas for 1961, 1962, and 1963, insecticide treatments on fixed schedules required an average of 12 treatments while treating based on scouting lead to a later starting date and 5.67 treatments per season. However, scouts may not always give farmers correct recommendations based on pest counts. W. P. Boyer in an unpublished report examined the extension scouting records for 4738 fields in 1971. Scouts recommended treating 1561 or 33 percent of the fields with infestations below recommended rates. In a majority of the cases farmers treated when the scouts recommended treatment. In many cases farmers treated fields when no recommendation or "recommended not to treat" was the report. Scouts failed to recommend treating a small percent of fields that had reached established treatment levels.

The final set of data on early season treatments is shown in Table 3.4. It gives percent of fields surveyed by extension scouts which were treated with insecticides in each week. Recall that of the years shown weevil populations were above threshold levels in a larger percentage of the fields in 1966, 1967, and 1971 (Table 3.3). There does seem to be some reduction in treatments with time. Comparing two years of similar degrees of infestation above threshold (1965 and 1971), one can see that 1971 has fewer treatments during June to mid July. Some of the reduced insecticide use may be attributable to more scouting in 1971 than 1965.

(iii) The effect of infestation records on marginal productivities of insecticides: Insecticides and scouting can be considered as joint inputs in the cotton production process. One measure of the influence of scouting would be to see how the inclusion of actual infestation records changes the marginal productivity of insecticides. Assuming that the production process can be specified as a power function and that variable factor prices are constant across farms in a given year, the production process can be written as:

$$Y_{it} = \sum_{j=1}^{8} b_{ij} X_{ijt} + \sum_{t=o}^{3} b_t D_t + E_{it}, \qquad \begin{array}{l} i = 1, 2, \ldots\ldots 509 \text{ farms} \\ t = 1964, 1966, 1969 \end{array}$$

Where all variables written in terms of logs are:

Y_{it} = the cotton lint revenue on farm i in year t

X_1 = insecticide expenditures

X_2 = fertilizer and lime expenditures

X_3 = herbicides and other material expenditures

X_4 = land rental rates

X_5 = hired labor payments

Table 3.4. Percent of Arkansas Fields Treated by Week[a]

Year	June		July					August			
	3	4	1	2	3	4	5	1	2	3	4
1962	5	5	13	15	27	55	76	85	90	80	77
1963	5	3	4	6	11	25	52	68	74	77	79
1964	3	3	3	4	16	42	44	30	54	58	58
1965	2	2	2	6	21	40	48	55	67	71	67
1966	17	5	2	1	6	11	23	38	54	73	80
1967	0	2	1	5	26	48	66	79	86	91	92
1968	4	1	1	3	5	12	32	39	53	67	73
1969	1	1	4	4	7	22	46	61	65	66	69
1970	0	1	1	1	11	27	47	66	63	71	78
1971	0	2	1	2	8	19	41	64	67	77	-
10 year mean	3.7	2.5	3.2	4.7	13.8	30.1	47.5	58.5	67.3	73.1	74.8

a - from "Cotton Insects in Arkansas, 1959-1973," all available consistent records
Note that these records are only from extension scouted fields.

X_6 = power and equipment maintenance, operation and depreciation charges

X_7 = custom expenditures

X_8 = index of bollworm infestation by counties in terms of percent of weeks with greater than 5 percent square damage

$D_{1,2}$ = index for 1966 and 1969 year effects

E = error term

The model was estimated using data from the USDA, Cotton Cost Survey for 1964, 1966, and 1969 for Delta farms. The parameter estimates with X_8 (equation 1) and without X_8 (equation 2) are:

$$(1)\ Y = 2.897 + \underset{(4.14)}{.0147X_1} + .0616X_2 + .300X_3 + .183X_4 + .258X_5 + .115X_6$$

$$+ .027X_7 = \underset{(.54)}{.253D_1} - \underset{(1.64)}{.046D_2} \qquad R^2 = .94$$

$$(2)\ Y^* = 2.994 + \underset{(5.02)}{.0182X_1} + .060X_2 + .306X_3 + .178X_4 + .254X_5 + .114X_6$$

$$+ .028X_7 - \underset{(4.16)}{.044X_8} - \underset{(.25)}{.255D_1} - \underset{(.43)}{.012D_2}$$

$$N = .527 \qquad R^2 = .94$$

The major effect of the inclusion of bollworm infestation records (X_8) was to increase the coefficient on insecticide expenditures ($\hat{b}_1$) by about 24 percent from .0147 to .0182. (Note that t values are given below several key variables only. All other variables except the year dummies were significant at the .05 level.) The precision of the estimate of $\hat{b}_1$ is also increased (t values rises from 4.14 to 5.02). The marginal value product of insecticides can be computed as:

$$(3)\quad MVP_{x_1} = \hat{b}_1 \cdot \bar{Y}/\bar{X}_1.$$

The value of insecticides and scouting - assuming \$1.00 per acre scouting costs is:

(4) $MVP_{x_1 + x_8} = \hat{b}_1 \cdot \bar{Y}/(\bar{X}_1 + \bar{X}_8)$ from equation (2), where $\bar{X}_8$ is \$1.00 x cotton acres per farm. The MVP estimate from equation (4) is \$2.53. Insecticide expenditures and scouting expenditures were profitable ones on average in the Delta in the mid to late 1960's. The equilibrium price of scouting information (where $MVP_{x_1 + x_8} = \$1.00$) would be at a price of scouting of \$3.20 per acre. Note that this estimate is based on accurate scouting. A more realistic view of the marginal productivity of scouting may be obtained by evaluating individual farm scouting efforts - both hired and managerial.

A-2 Benefit Measures of Pest Management in North Carolina

(i) Yield Comparisons: In the 1973 Annual Report of the USDA sponsored Pest Management Program in North Carolina it was estimated that those growers in three cooperatives in 1973 received a net profit of \$95 per acre more than neighboring growers who were not part of a spray group. At the same time it was acknowledged in the report that 1973 was the most severe bollworm outbreak in recent years. As the annual report indicates, benefits of scouting and having chemicals and aerial application on contract would probably be less in less severe pest years.

Two cotton yield comparison studies besides the USDA study were conducted in North Carolina. The first was a sample of farmers in the group referred to as cooperative number 4. Agricultural Stabilization Commodity Service (ASCS)—recorded yields for 22 farmers who were in the cooperative in 1973 (Group A) and 17 farmers who joined the cooperative in 1974 (Group B) were compared. (Growers were randomly selected from the 39 who were in in 1973 and the 69 in in 1974). Yields were compared for 1971, 1972, and 1973.

	Group A 22 Members of[a] No. 4 Cooperative, 1973		Group B 17 Members Who[b] Joined No. 4 Cooperative, 1974	
Year	Average Yield	σ	Average Yield	σ
1971	315.6	165.9	182.2	141.2
1972	369.1	164.3	211.4	183.3
1973	589.1	244.1	188.1	188.8

differences 1971-134 lbs., 1972-158 lbs., 1973-401 lbs.

a - these growers held 56 allotments
b - these growers held 49 allotments

For each year the difference between the mean yields are significant at the .01 level. The coefficient of variation is also smaller for group A than for group B. However, one cannot be certain which resources are contributing to the yield differences. We only know that existing members in 1973 have higher yields than new members for 1971, 1972, and 1973. Records of membership in past years were not available to determine yields of those in group A who were not members in 1972 and 1971. The ASCS records both actual yields and "adjusted" yields for individual farmers. The adjusted yield is the best of either the actual yield or 90% of the average of the past three years adjusted yield. In 1971, 42 of the 56 allotments in GROUP A had adjusted yields above their actual yields. These adjusted yields averaged 388 lbs./acre. For the 49 GROUP B allotments the corresponding numbers were 46 and 346. If we assume that the historical difference between the groups was 38 lbs. then the difference due to the cooperative is 1971-96 lbs., 1972-120 lbs., and 1973-363 lbs. These are all significant differences at the .01 level.

The second yield comparison is for all members in cooperative No. 9 compared with all non-coop cotton growers in the same county. ASCS yield records for 3808 acres in the cooperative and 3087 acres not in the program were compared for 1973 as follows:

Coop No. 9 Average Yield	Non-Coop Members Average Yield
607	403

Given that the average farm size is about 60 acres of cotton, there were about 65 cooperative members and 50 non-cooperative members. The difference of 204 pounds is probably significant if the variation between farms is similar to that of cooperative 3 in 1973.

In any event, most non-cooperative members is the county judged the yield difference to be economically significant, because all but 3-5 joined in 1974. Marginal costs of participating in the program compared with not participating for 1973 were about $1.20 for scouting, $1.50 for management and overhead and perhaps one additional in-season treatment at about $2.85 for a total of $5.55 (see Table 3.8). Therefore, at an expected lint price of $.50 only a difference in yield of 10 lbs. of lint per acre is needed to justify joining a spray cooperative. The probable reduced variability in yields is an additional utility gain.

(ii) Relationship of percent acres scouted to deviations from predicted yield: A model was developed to predict county yields of cotton prior to the beginning of the cooperative pest management. It was felt that if a high proportion of county average yields could be "explained" with monthly rainfall, temperature, weevil infestation, farm size, and county fertility variables, then deviations in actual from predicted yields could be plotted against percent of county yields scouted (from the organizations listed on Tables 1.2 for 1972 and 1973). Parameter estimates and t values for a linear, multiple regression model are given in Table 3.5. Most variables are statistically significant. Sixty-eight percent of yield variation is explained. Only two of the twenty-one independent variables have unexpected signs, October rain and May temperature, the latter is non-significant.

The deviations from predicted yields based on parameter estimates of Table 3.5 are plotted against acreage scouted in Figure 3 and 4 for 1972 and 1973, respectively. In 1972 the county with the lowest residual (-80 lbs.) had no scouting. Five of seven counties with scouting had residuals greater than + 100 lbs. In 1973 all residuals were positive with most counties about 200 lbs. above predicted yields. The three counties with the highest unexplained yields also had the largest share of the cotton scouted.

B. Program and Farm Costs

B-1 Arkansas

The major cost categories of pest management to growers are insecticide materials, application costs and scouting. Costs of insecticides have risen sharply in 1974 from 1973 levels. Aerial application costs are up about ten to fifteen percent and scouting costs are up about ten percent.

Scout wages have not seemed to rise as rapidly as daily farm wage rates in Arkansas. Table 3.6 shows available scouting wage data for 1960 to 1974. The index of daily farm wages rose much more rapidly, probably due to the increased skill levels required during the 1960's.

Scouts were assigned to work areas away from their homes prior to about 1965. However, this was discontinued so they could live at home. Many

Table 3.5. County Yield Per Acre Regression Coefficients, North Carolina 1957 to 1966.

Variable	Coefficient	t value for H_o B = 0
Intercept	2761.12	4.08
Year	- 11.98	-3.26
April Temp.	- 1.28	- .38
May Temp.	- .53	- .14
September Temp.	- 16.32	-3.73
October Temp.	- 5.62	-1.68
April Rain	12.16	2.40
May Rain	- 8.23	-2.38
July Rain	- 2.59	- .84
October Rain	7.19	3.09
X_1 Cleveland	- 78.10	-1.55
X_2 Edgecomb	25.68	.66
X_3 Halifax	7.95	.19
X_4 Nash	1.88	.05
X_5 Northampton	8.90	.22
X_6 Johnson	- 17.26	- .43
X_7 Harnett	- 39.19	- .95
X_8 Hoke	- 43.91	-1.45
X_9 Robeson	- 21.19	- .61
X_{10} Sampson (Scotland)	- 9.16	- .24
Farm	2.10	2.69
Weevil	- 32.95	-3.24
R^2	.68	
n	121	

Explanation of independent variables:

Year - a 2 digit number was used for the year from 1957 to 1966.
Temp - average monthly temperature as reported in North Carolina Climatological Reports for the weather station either most centrally located in or nearest the individual county. Temperature was recorded in degrees fahrenheit.
Rain - total monthly rainfall in inches..
X_1 - X_{10} - zero-one dummies to attempt to account for soil and other differences.
Farm - average county farm size in acres.
Weevil - a scale of 0 to 4 was constructed from reports in Cooperative Economic Insect Reports. The same number was used for all counties in the state for a single year.

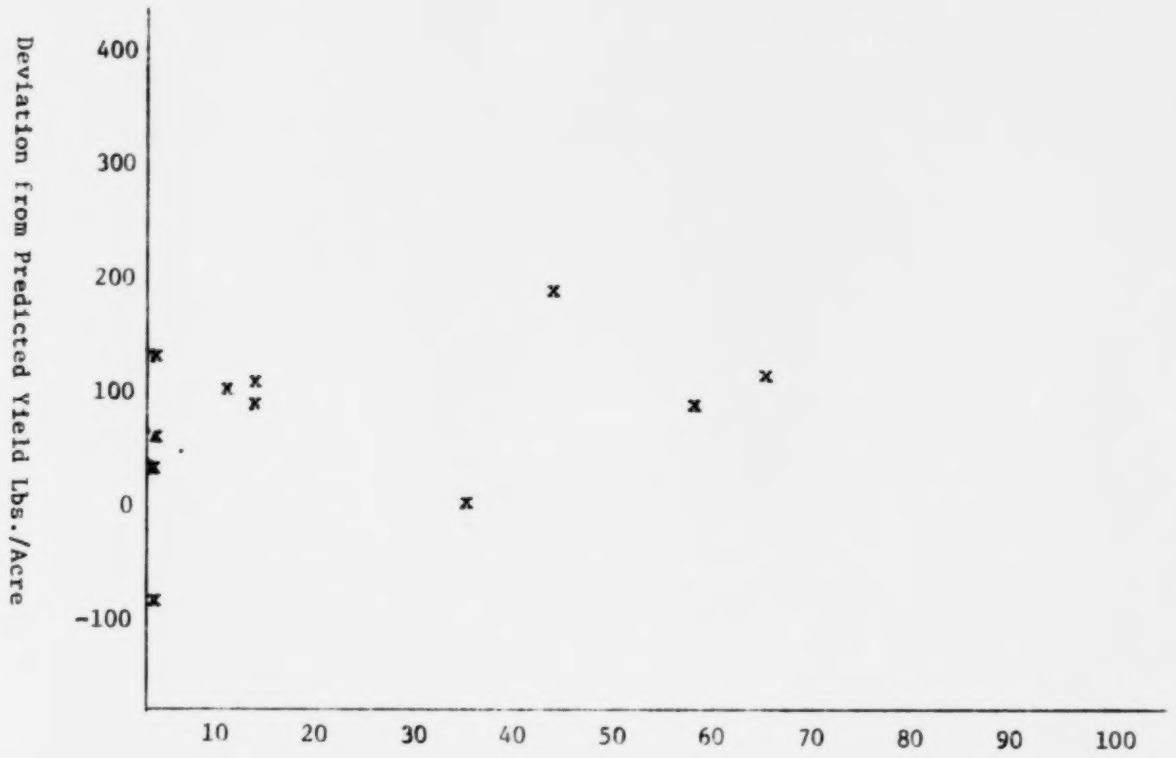

Figure 3. Percentage of County Acreage in Scouting Programs, 1972

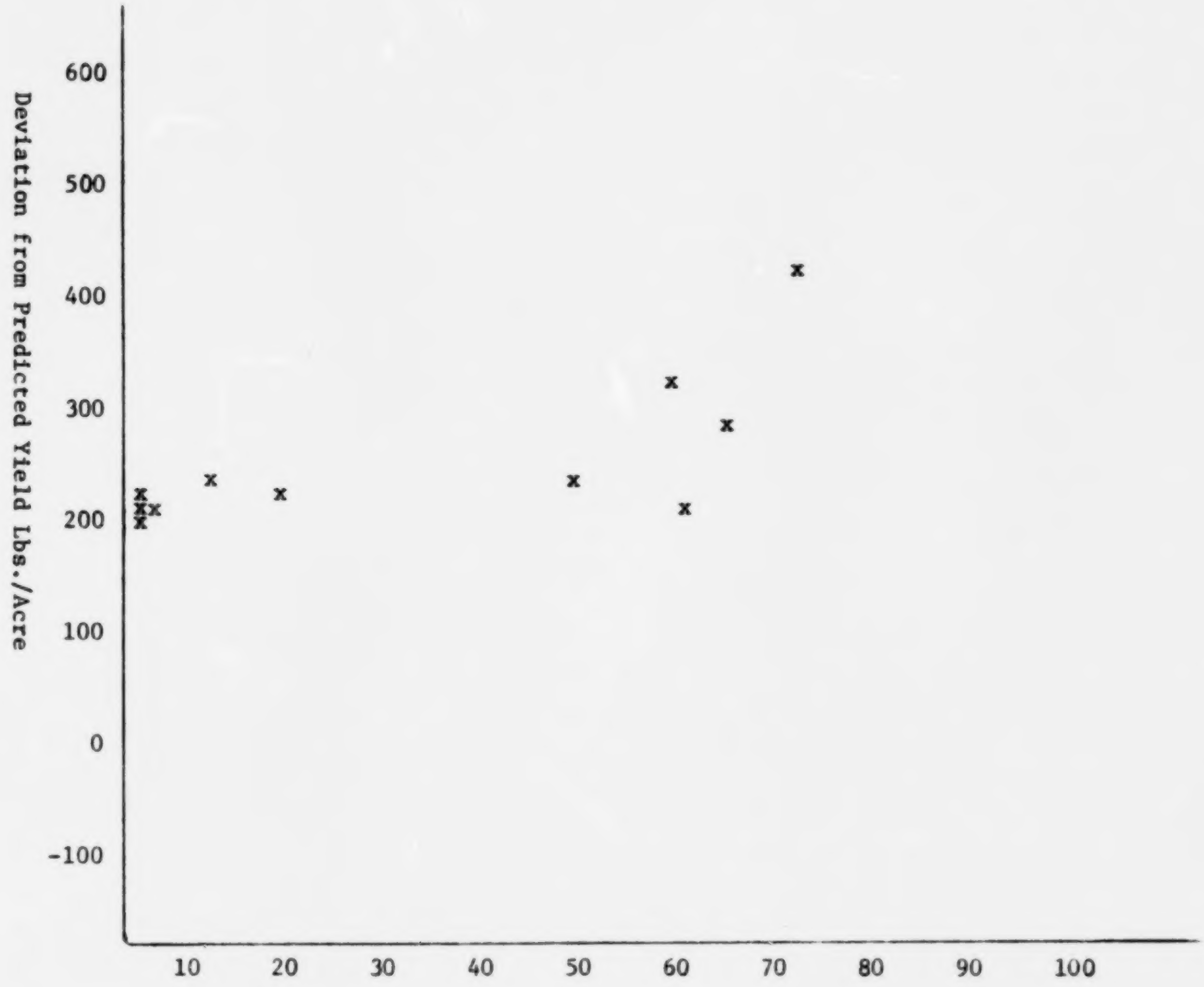

Figure 4. Percentage of County Acreage in Scouting Programs, 1973

Table 3.6. Estimates of Direct Scouting Costs-Arkansas, 1960-1974

Year	Jefferson County	Mississippi County	Arkansas Average[a]	Arkansas Index of daily farm wages[d]
		($ per acre)[b]		
1960	.76		.75	100
1962	.87		.88	109
1964	.85		.88	118
1966	.85		.90	137
1968	.98		.96	168
1970	.994		.98	214
1972	.964	.86[c]	.98	215
1974	1.22	1.10[c]	1.15	220

a - based on 25-35 percent sample of scout wages from cooperative extension service files - includes wages plus travel cost

b - assumes 11 weeks of work, 2 man scout crew for travel, 1350 acres per scout prior to 1970, 1400 acres per scout after 1970.

c - records of county extension entomologist

d - Bureau of Labor statistics

schools and universities changed to an earlier start in the fall beginning in 1971. This has caused reduced scouting in the last week of August and the first week in September. Both of these changes, residence of scouts and termination date has lowered scouting costs. Some specialists believe that these factors have also reduced scouting effectiveness. A scout may be more reluctant to give a neighbor farmer than an unknown farmer "no-treatment" recommendation if pest populations are near, but below, the threshold.

Table 3.7 gives estimates of total pest management costs per acre scouted. Costs to growers are about 10 to 16 dollars in recent years for insecticides, application and scouting. Insecticide costs rose sharply in 1974 from the increased price of materials (approximately 40 percent) and increased numbers of treatments (from 4 to 5). Scouting costs of approximately $1.00 per acre are small relative to application and insecticide costs. Insecticide prices per unit have risen at about the same rate as scout wages from 1960 to 1974 (about 50 percent). However, from 1972 to 1974, insecticide prices have risen about 50 percent while scouting costs have only gone up 17 percent. Thus, we should expect more scouts relative to insecticides to be utilized in the near future.

Public costs are given in Table 3.7 by category. One of the major costs is county agent time to hire scouts, help supervise them, contact growers and collect scouting fees from growers. A limited survey of agents, and estimates by state officials place the man-years of labor at about .25 per county. Some counties have trained agronomists and at least one county has a trained entomologist. The other major cost components are professional time and scout supervisors. As shown in Table 1.1 scout supervisors in Arkansas have risen from 1 to 7 in recent years. This is

Table 3.7. Arkansas Cotton Pest Management Costs

	1960	1972	1973	1974
		Cents Per Acre		
Scouting				
Scout wages	75.00	96.92	103.50	113.27
Scout travel	1.00	1.08	1.43	1.73
Scout Supervisors[a]	1.06	4.29	8.39	9.86
County Agents[b]	22.50	25.46	28.19	28.80
Professional Support	6.30	7.29	9.14	9.02[c]
Computer	0	3.78	6.26	6.47[d]
Other Overhead	.30	.38	.46	.50[d]
Insecticides[e]	600.0	720.0	540.0	950.0
Plane	375.0	540.0	360.0	500.0
Total	$10.81	$13.99	$10.57	$16.20
Total paid by growers	10.51	13.58	10.05	15.65
Total public	.30	.40	.52	.55

a - includes travel
b - salaries at $10,000 per year; .25 man years per county for 1972-1974, salaries at 8,000 and .2 man years in 1960.
c - 105 percent of 1973 wages
d - 110 percent of 1973 costs
e - based on average number of treatments of 1960-5.0, 1972-6.0, 1973-4.0, and 1974-5.0

to help assist in training, prevent shirking, and assist scouts in their treatment recommendations to growers. Professional time has been an extension entomologist, an assistant extension entomologist, and a survey entomologist who have also had to service other crops. The research component is not included. The research staff involved in cotton pest management in Arkansas appears to involve three to five faculty members and an equal number of graduate students during the 1960's. Total public costs excluding the research component is 40 to 55 cents per acre in recent years.

B.2 North Carolina Program and Farm Costs

Program costs have risen rapidly in North Carolina between 1973 and 1974. (Estimates of costs to growers by organization, by acre, and by application are given in Tables 3.8 and 3.9, respectively). This is principally due to a large increase in the cost of chemicals. The price of one widely used chemical rose from $4.50 per gallon in 1973 to $7.50 per gallon in 1974. Application costs have also risen. Scout salaries are a relatively small part of the total program cost and are budgeted in various programs from $1.20 to $1.50 per acre per year. The cost per acre per week scouted varies widely from a high of $.16 per acre per week to a low of $.07 per acre per week. This is due to number of times per week a field is scouted and wage rates. Total scouting costs of course depend on the number of weeks the scouts are employed which does vary among groups. The chairman of the group with the low cost considers he does not have enough scouts and only scouts each field every second week. The group with a scouting cost of $.16 per acre per week pays its scouts by the field rather than by the week. This is the first year that they have done this. Most groups spend from 11 cents to 13 cents per acre per week on scouting (see total costs, Table 3.10).

Table 3.8. Costs to Growers Per Acre Scouted by Groups - North Carolina

	1974			1973			1972		
	Total	Scouting	Spraying	Total	Scouting	Spraying	Total	Scouting	Spraying
		(Dollars)			(Dollars)			(Dollars)	
Cooperatives									
1	42-44	1.20		28	1.00				
2	44-50			32					
3	40								
4	42		37	30			24.85		23.00
5				30.50		25-26			
6		1.25-1.50							
7	40		37	39					
8	40-41			31.50					
9	46[a]	1.50[b]		35[a]	1.36		28.0		
10	45-46			39					
11							26.35		24.60
MEAN	42.62[c]	1.35		33.12			26.40		23.80
Commercial Operations									
1		1.50			1.25				
2									
3		1.25			1.00				
MEAN		1.375			1.125				

– excludes funds collected for 2 diapause treatments

b - scouts paid $1.50 per field per week

c - estimated total as of August 15, 1974; rains during August will probably increase treatments and lead to further operating fund requests

Table 3.9. North Carolina Grower Cooperative Costs Per Application

	1974			1973		
	Chemical	Plane	Total[c]	Chemical	Plane	Total[b]
Cooperatives						
1						2.44
2	2.50	1.25	3.75			2.67
3						
4			3.70			2.73
5						2.77
6		1.00-1.50				
7	2.13	1.67	3.80			
8						2.86
9	2.40	1.20[a]	3.83	1.65	1.10	3.17
10						3.12
11						
MEAN	2.34	1.34	3.71			2.82

a - 1.15 for less than 1/2 gallon per acre, $1.35 for more than one gallon per acre.

b - includes chemical, plane, management and scouting

c - includes chemical and plane only

Table 3.10. North Carolina Public and Private Program Costs

	Dollars Per Acre Scouted		
	1972	1973	1974
Grower Costs			
Scouting	1.15	1.18	1.35
Insecticides	13.00	15.50	25.74
Application	10.80	11.74	14.77
Management and overhead	1.45	1.80	2.05
Totals	26.40	30.22[c]	43.91[a]
Public Costs[b]	.56	1.61	1.46
Totals	26.96	31.82	45.37

The total cost to the grower has risen from an average of $33.12 in 1973 to an average of $42.62 in 1974 (see Table 3.8). This increase mav represent some extra program services as more programs are planning diapause treatments in 1974. If these diapause treatments are effective they should lower the program cost in future years. For example, the group with the highest farmer cost per acre had one of the best diapause programs last year and considers that it did reduce the need for early spraying this year.

Public and private program costs are given in Table 3.10. Public costs were low in 1972, as the USDA program was just getting started and did not become fully operative until 1973. Public costs are a small part of total costs; about the same as grower paid management costs.

C. Environmental Impact of Pest Management

C.1 Arkansas

The major indicator of environmental degradation in the case of pesticide use is assumed to be the total quantity of materials applied. In the section on benefits data were presented which showed that scouting can and probably has led to later starting dates for insecticide applications. This is due to scouting and to reduction in over-wintering habitat for the boll weevil in the southern Delta area.

Several estimates of insecticide use on cotton are available and are given in Tables 3.11, 3.12, and 3.13. Table 3.11 gives the 1969 Census of Agriculture figures and shows that the 5-9 application range was the most frequent application rate. Fifty-nine percent of the principally cotton farms, 46 percent of the diversified (cotton as secondary crop), and 67 percent of the small cotton farmers (< $10,000 gross sales) applied 4 or fewer treatments per acre of cotton grown. The average number of treatments is not possible to estimate accurately because of the open-end upper category. However, assuming

Table 3.11. Number of Insecticide Applications - Arkansas, 1969

	Sample of all Cotton Farms Number of Applications							
	0	1-2	3-4	5-9	≥ 10	Acres per farm	farms	cotton acres
	(percent of farms)							
Arkansas Farms								
Principally cotton	31.3	16.3	11.5	28.5	12.3	239.9	1950	467,749
Cotton as secondary crop	21.5	12.2	12.6	41.7	12.0	277.6	1106	307,479
Less than 10,000 sales	43.9	10.5	12.9	23.4	9.4	47.7	1368	61,096

Average Number of Applications (≥ 10 assumed to be = 12)

Principally cotton	4.1
Cotton secondary	5.0
Less than 10,000 sales	2.5

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a - Census of Agriculture, 1969 - Arkansas

Table 3.12. Insecticide Use Estimates - County Agent, Arkansas[a]

Year	Average Treatments Per Acre Treated	Percent of Acreage Treated at Least Once
1959	5.3	89
1960	5.0	85
1961	6.0	62
1962	6.5	68
1963	6.0	60
1964	4.3	58
1965	5.2	73
1966	5.0	
1967		
1968		
1969		
1970		78
1971		
1972	6.0[b]	
1973	4.0[b]	
MEAN	5.33	71.6

a - From "Cotton Insects in Arkansas," 1959-1973
b - From scouting records

Table 3.13. Arkansas Insecticide Expenditures Per Cotton Acre Harvested[a]

County	1964	1966	1969
Arkansas			8.42
Craighead	.45	2.59	1.07
Crittenden	1.63	2.56	
Cross	2.21	3.30	1.35
Desha	6.88	7.83	
Green	.41	2.09	.98
Jackson	1.52	2.55	2.39
Lawrence	.06	.61	
Lonoke	8.28	9.04	
Jefferson			8.40
Mississippi	.50	1.23	
Monroe	6.33	6.10	5.47
Poinsette	.75	4.50	2.67
Prairie	1.62	7.25	4.24
St. Francis			4.37
Woodruff	6.09	7.39	
MEAN	$2.83	$4.39	$3.94
Number of farms in survey	390	402	230

a - From "Costs of Producing Upland Cotton," ERS, USDA, TAB-II, Tapes 1964, 1966, 1969.

that the greater than or equal to 10 treatments has an average value of 12, gives average treatments of 4.1 for principally cotton, 5.0 for diversified, and 2.5 for small producers.

Table 3.12 gives county agent estimates of insecticide use for 1959-1966 and estimates of use from records of scouted fields in 1972 and 1973. The overall mean appears to be near 5 treatments per season with no observable trend. The percent of acreage treated at least once was about 70 percent, also with no observable trend.

The final estimate of insecticide use is in terms of expenditures per harvested acre by counties and is given in Table 3.13. Mean levels of expenditures are $2.83 to $4.39 per acre. At $.90 per treatment, and with 30 percent of the acreage untreated this leads to mean application rates per acre treated of: 1964-3.1, 1966-4.9, 1969-4.4.

C.2 North Carolina

Cotton farmers are large scale users of insecticides. Table 3.14 shows the average number of insecticide applications for a sample of all cotton farmers in the state for 1969. These figures are lower than the figures in Table 3.15 for farmers in the cotton scouting program. This would indicate that the programs may have increased insecticide usage. However, those growers who have less severe insect problems would not be likely to join a scouting and spraying organization. Also, the cotton price support system (prior to 1974) has sometimes lead to cotton being grown on inferior land using as few inputs as possible merely to receive support payments. These growers would not likely use much insecticide , nor would they be likely to join a cooperative program for thirty or more dollars per acre.

Table 3.14. Number of Insecticide Applications - North Carolina, 1969[a]

	Sample of all Cotton Farms Number of Applications 0	1-2	3-4	5-9	≥ 10	Acres per farm	farm	cotton acres
North Carolina	(percent of farms)							
Principally cotton	9.1	10.6	9.1	37.9	33.3	66	15,495	234.8
Cotton as secondary crop	12.7	8.5	2.2	27.6	51.5	134	31,000	231.3
Less than $10,000 sales	26.6	6.3	0.0	62.5	6.3	128	5,944	46.4

Average Number of Applications (≥ 10 assumed to be 12)

Principally cotton	7.1
Cotton secondary	8.3
Less than 10,000 sales	5.2

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a - Census of Agriculture, 1969, North Carolina

Table 3.15. Insecticide Use by Cooperative and Commercial Groups, North Carolina

	Applications Per Season					
Cooperative Groups	1974[a]		1973		1972	
	Regular	Diapause	Regular	Diapause	Regular	Diapause
1	10[a]	1[a]	9-12	1		
2	13[a]	1[a]	11	1		
3						
4			9-11	1	9.8	
5			11	2[b]		0
6	10-12[a]		9-13			
7	11[a]	1[a]				
8			10-12			
9	12[a]		11	2[c]		
10	13[a]	1[a]	12-13			
11	7[a]		8	3[d]	11.9	
MEAN	11		10.67		10.8	
Commercial Operations						
1						
2	15 +[a]		12			
3			8-12	80%		

a - estimates as of August 15, 1974
b - only on 1800 of 2600 acres
c - only about 3200 of 4800 acres
d - only 700 of 2800 acres

The cooperative programs undoubtedly reduce the risk of pesticide injury to farmworkers and others. The groups buy their chemicals in large containers if possible and usually take some care in disposing of the containers. They also have good equipment for transferring chemicals from containers to application equipment without spillage. Spraying and scouting schedules are set up so that the scouts do not enter the fields until a safe period after the last spraying. Since most of the groups are in close contact with extension personnel they will probably respond faster than unorganized farmers to changes in suggested chemicals usage and application rates.

Effect of Spray Programs on Starting Dates of Regular Treatments, North Carolina

It appears that a scouting program combined with diapause control can reduce the need for blanket spraying for boll weevils early in the season. Two of the groups were able to defer complete spraying until August by selectively spraying for the boll weevil. One group had not sprayed two thirds of its acreage at all as of August 1 (Group 11 in Table 3.15). Two groups were able to defer regular spraying until about July 10 and most groups were able to pause after the first two or three sprayings for a period of one to three weeks.

The scouts and light traps enable the groups to use the most effective chemicals against the pests that are present and also enabled many of the groups to stop spraying for the boll weevil and wait until the bollworm moth occurred before resuming spraying.

IV. Summary and Projections

There are many possibilities and constraints for future development of pest management in North Carolina and Arkansas. This section will summarize both tangible and intangible inducements for change.

A. Constraints on Expansion of Cotton Pest Management

In Arkansas the main restriction on expanded pest management seem to be ineffective scout recommendations. This probably has been partially corrected in the past few years with the increase of scout supervisors from 1 to 7. Yet, the number of scouts per supervisor (22) remains high. Given the rising price of insecticides relative to labor and the indication that about 12 percent of all farms were still applying 10 or more treatments per acre of cotton grown, there appears to be further possibilities for substitution of labor for insecticides.

It probably is not essential that large proportions of acreages be scouted in a county (see Figure 2 for diminishing returns). But the presence of some extension scouting in all cotton counties seems advisable. Thus, a major shortcoming of the existing program is the absence of substantial county agent input in scout training in many cotton counties. Also, evidence was given that smaller cotton growers are not participating in purchase of extension scouting services as readily as large farmers.

There is substantial information on pests, crop conditions, and scouting activity in Arkansas. There is much less understanding of the part of growers, aerial applicators and insecticide sales firms on insecticide use decisions. About 6-7 million acres are treated once over each year. More complete information on insecticide usage, shortages and response of growers to prices is needed. Little is known about the opportunity cost of cotton grower time at various weeks in the cotton season. This is essential if recommendations given growers are to reflect the constraints on management time which seems to be a major ingredient in Arkansas pest management.

The state and county information on pest threats during the season seems to be quite good. Yet, little use seems to have been made of much of the information collected by scouts and compiled in computer files. Recent developments in quantitative entomology have only been pursued to a limited extent because of limited research resources.

In North Carolina there are several constraints on pest management expansion. The major problem in the cooperatives is shortage of trained and experienced managers. Farmer directors will not trust inexperienced entomology graduates, and there seem to be few with long experience. On the other hand, the short duration of the scouting season (3 months) makes a full time cooperative manager too expensive. Farmer managers are limited because of the time demands of other crops.

A second problem with the cooperatives is their need to expand to cover overhead costs and include a wide enough area for diapause control to be effective. If they become too large then scouts go unsupervised, fields are missed during selective treatments, and disagreements among members increase. These are typical cooperative problems but the spray cooperatives have the added dimension of a mobile pest. The diapause program effectiveness depends upon proportion of the surrounding habitat in the cooperative program.

The third area of concern is the relatively undeveloped warning system for bollworms. Research on the flight patterns of bollworms is in progress but has not been implemented in the control program. In the short term, there appears to be insufficient use of light traps, sugar lines, radio announcements and other warnings, especially in counties where cotton production is less than 5,000 acres.

The larger, more specialized growers in the southern part of North Carolina do not seem to be willing to participate in cooperatives. They have fewer crops competing for their time during July and August. Many farmers scout their own fields. Many are also being served by the commercial scouting firms. The major shortcoming of these relatively new services is their combination with chemical and application services. There is some indication that the commercial firms recommend, and result in higher insecticide use. Also, these firms tend to exclude contracts with smaller cotton farms. Research and extension advice is being given to commercial scouting firms, but probably not nearly to the extent as to cooperatives. Given the productivity of commercial scouts in other states, the extension support to these groups should probably be expanded.

B. Summary of Future Possibilities

This study summarizes several measurable benefits of cotton pest management: reduced early season treatments, increased participation in extension scouting in northern Arkansas, increases in yields as degree of scouting rises in both states, increases in marginal productivities of insecticide in Arkansas, increased yields upon joining cooperative pest management groups in North Carolina.

Apart from their measurable benefits in increasing yields and reducing early season treatments, these programs have other, intangible benefits.

The large volume of data being collected has already, and will in the future aid researchers in various areas. The Arkansas data has already been used in several research projects in the areas of insect population growth and plant damage and growth. Much more data is being collected than an individual researcher could hope to obtain in controlled experiments. With this large data base, it may be possible to determine the effects of many different factors of plant and insect growth on crop yield.

The cooperatives in North Carolina are possible organizational structures for introducing and contracting for other technologies which have scale economies such as soil tests, nematode checks, and fertilizer recommendations.

In both states pest management trains scouts. Over 1200 different individuals have participated as scouts in Arkansas in the past 25 years. Many former Arkansas scouts are leading research and extension entomologists. In North Carolina, some scouts receive college credit for scouting experience. Clearly, hundreds of farm operators are better able to scout their own fields.

The expansion of pest management in cotton in Arkansas is very probable. Relative insecticide-labor prices favor its growth. New technological changes such as sequential sampling and road side scouting may lower scouting cost per field per season. More supervision will improve scouting effectiveness.

Expansion of cooperatives for pest management in cotton and other crops is likely. Peanuts, soybeans and tobacco insect, disease and nematode scouting can reduce the management costs per dollar saved by expanding the season. Commercial firms which provide fertilizer, variety, planting and pest control advice are likely to expand. Growers seem willing to contract for these services from reliable vendors.

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Appendix C-i

EVALUATION OF
PEST MANAGEMENT PROGRAMS FOR COTTON
IN CALIFORNIA AND ARIZONA

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TABLE OF CONTENTS

Page

Introduction C-1

Specific Program Evaluations C-6

California Pest Management Consultants C-6

Characteristics of Consultant Users C-9

Description of Program C-9

Effectiveness of the Consultant's Program C-11

The California Cotton Scout Program C-21

Description of Programs C-21

Economic Evaluation C-26

External Effects and Environmental Impacts C-30

Long-Run Viability and Technical Expansion Constraints C-39

Arizona Pest Management Programs C-41

Graham County Program C-42

Pinal County Program C-43

Overall Feasibility of Integrated Pest Management in California and Arizona C-49

Applicability of Findings of Other Crops C-52

APPENDIX I Projections of Acreage Under Pest Management Control in the San Joaquin Valley for 1973 . . . . C-53

APPENDIX II California Cotton Pest Management Program, 1974, Field Inspection and Reporting Techniques C-54

LIST OF TABLES

Table — Page

1 Consultant Program, San Joaquin Valley, California, 1970-1974 . . . . C-7

2 Acreage in Consultant Program and Total Cotton Acreage, By County, San Joaquin Valley, California, 1970-1973 . . . . . C-8

3 Yields, Revenues, and Cost to Cotton Farmers: Adopters and Nonadopters of Pest Management Consultants, San Joaquin Valley, California, 1970-71 . . . . C-12

4 Cotton: Average Yield Per Acre, San Joaquin Valley, 1970 and 1971 . . . . C-14

5 Cotton: Average Insecticide Expenditures Per Acre, San Joaquin Valley, 1970 and 1971 . . . . C-15

6 Insecticide Costs Per Bale for Adopters and Nonadopters of Cotton Pest Management Consultants in the San Joaquin Valley, California, 1970 and 1971 . . . . C-16

7 Regression Coefficients and Statistics Illustrating Strong Negative Correlation Between Insecticides Per Bale and Farm Size for Nonadopters of Pest Management Consultants, San Joaquin Valley, California, 1970-71 . . . . C-18

8 Cost Breakdown for Consultant Program, San Joaquin Valley, California, 1971 . . . . C-19

9 California Scout Program, 1972-1974 . . . . C-24

10 Returns Per Acre to Cotton Farmers in 1973 . . . . C-28

11 Occupational Disease Attributed to Pesticides in the Cotton Growing Counties, California, 1971 . . . . C-34

12 Reports of Occupational Disease Attributed to Pesticides, By Industry Group, California, 1971 . . . . C-35

13 Fish and Wildlife Losses Due to Pesticides Used in Cotton Production, 1965-1969 . . . . C-37

14 Arizona IPM Programs C-44

15 Insecticide Costs of Adopters and Nonadopters of Economic Threshold Practices, Cotton Scout Program, Pinal County, Arizona, 1972 and 1973 . . . . C-47

16 Cost Breakdown for All Participants, Cotton Scout Program, Pinal County, Arizona, 1972 . . . . C-48

AN EVALUATION OF INTEGRATED PEST MANAGEMENT PROGRAMS FOR CALIFORNIA AND ARIZONA COTTON

by

Richard B. Norgaard[1]

Introduction

This report evaluates the economic viability of integrated pest management (IPM) programs used on cotton in California and Arizona. For the purposes of this evaluation, an IPM program involves systematically integrating introduced controls, largely chemical, with natural controls and cultural practices. The term, economic viability, is interpreted broadly to include the extent to which farmers will individually or collectively adopt an IPM program as well as whether and to what extent it appears to be in the public interest to subsidize an IPM program.

In both California and Arizona, private pest management consultants have provided pest management advice for many years of a quality that meets the above definition of integrated pest management. The continued existence of a pest management consultant industry directly attests to the economic viability of IPM in these states. But the success of the private consultants has been limited. Only about 20 percent of the cotton acreage in the San Joaquin Valley is under their program even though the industry has existed for nearly a quarter of a century. Thus, the problem of evaluation quickly becomes immensely more complicated than determining whether a program is economically attractive or not since for many years these programs have been attractive to some farmers and not to others. For several years the author and Wayne R. Willey have been investigating the factors which determine whether a farmer will adopt a consultant or not. While few definitive answers on this issue have resulted from our efforts, this report does embody considerable understanding of the problems gleaned from our earlier work.

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Two IPM programs used on California cotton grown in the San Joaquin Valley are evaluated in this study. The distinction between them is largely a matter of intensity. The first is the historic independent pest management consultant program involving field checking to determine the state of insect populations with pest control advice based thereon. This program has basically integrated natural predation and parasitism with chemical controls when necessary. A second, more elaborate program was introduced in 1972 by the Extension Service. This program involves increased frequency and regularity of field checking, greater and more systematic data collection, and pest management advice based on the state of insect populations and the stage and vitality of the plant. Thus, the second program is largely distinguished from the first in terms of effort required in data collection and in the level of attention given to the host plant.

Arizona cotton farmers in Graham County initiated a grower-financed field checking program in 1969 after two unusually heavy infestations of pink bollworm in 1967 and 1968. This program is largely patterned after the Arkansas scout programs in which Leon Moore, an Arizona Extension entomologist, had participated. Extension assisted in the establishment of the program and the training of the scouts, but the collective initiative of the growers probably reduced the burden on Extension entomologists overall. In 1971 a similar IPM effort was initiated in Pinal County with a subsidy through the USDA scout program. Data from the Pinal County program are evaluated in this study and assumed applicable to Graham County with some adjustments.

Pest management programs are inherently difficult to evaluate because appropriate control data for program comparison are nearly impossible to obtain. The roots of this difficulty lie in our basic inability to measure pest damage directly when it occurs in terms of its ultimate effect on yield and farm revenues. Consequently, when comparing the effectiveness of pest management programs, pest management inputs and crop yields can only be compared. Unfortunately, crop yields are dramatically affected by many factors in addition to pests and their management. These additional factors include, for example, the skill of the farmer in choosing the timing of inputs; the quantities of inputs such as water and fertilizer; soil quality; and local weather conditions. Soil and weather conditions can vary within even small regions as can the level of pest attack. Conceivably, data describing all of these additional factors which affect yield could be collected for farms in the pest management program and for farms in a control group. In fact, some of the factors are difficult to quantify and, like pest damage, their relationship to crop yield depends on the levels of all the other factors. The complex relationships between these factors are only now being explored through the use of computer simulation models of cotton plant growth.

For pest management programs involving many farms and extensive acreages, one might argue that the "law of large numbers" becomes effective--that the variation in the nonpest management factors is insignificant between the users of the pest management program and the control group. There are two fallacies to this argument. The first is that, without a better understanding of the underlying relationships, it is unclear when the law of large numbers comes into play. Second, the users of pest management programs are not randomly selected. The users of pest management programs choose to participate. Why farmers choose to participate is unclear. The following reasons are listed and stated in a manner to emphasize how nonrandom and important the "selection process" may be:

1. The farmer, having followed the best crop management practices and the Extension Service's previous recommendations for pest management, correctly recognizes that the new pest management program will further increase his yields and cut his costs.
2. The farmer, having practiced poor general crop management and then experiencing three disastrous years of pest resurgence due to excessive use of insecticides, joins the pest management program out of desperation but retains his poor crop management practices.
3. The managers of a large corporate farm fire their own in-house entomologist and join the pest management program in order to benefit from the program's federal subsidy.

The control data problem has further awkward ramifications. Pest management programs are difficult to define themselves. Farmers officially within a program may choose not to follow all of the recommendations of the program. Farmers not in the program, on the other hand, may choose to follow some of the practices of the program. In California, for example, the scout program is delivered by pest management consultants. These same consultants privately deliver the same program and a less intensive program to farmers. Farmers with some acreage in the scout program or privately utilizing consultants have been known to apply the recommendations given to fields within a program to fields "not in a program." Furthermore, many very large farms have their own in-house entomologists who provide pest management programs of varying degrees of quality. Furthermore, the traditional channels of pest management information, Extension entomologists and University publications, continue to be utilized by farmers. Lastly, chemical salesmen have had to deliver more and better pest management information in order to compete with pest management programs and answer the questions of increasingly informed farmers. In short, many levels of pest management sophistication are readily apparent, and each of these is gradually improving with time.

One possible approach to the control problem is to determine the change in the *relative* use of pesticides and crop yields of program participants before and after entering the program. For example, if program participants used 1.2 times the county average of pesticides and attained 0.90 the county average yield during the previous three years of the program and these statistics changed during the program to 0.6 and 1.0, respectively, then one would have a strong basis for evaluation. By comparing relative standing over sufficiently long-time periods, many of the problems associated with the nonpest management factors affecting yields and the nonrandom method of participant selection are substantially reduced. Records of preprogram yields of participants can be obtained through the cotton gins. A limited number of years of preprogram pesticide use for each participant in the California program and for the county or an appropriate region as a whole can be obtained from the pesticide use data collected by the state.

Though perfect control group data cannot be attained, attempts to overcome these difficulties provide some basis for evaluating pest management programs. Unfortunately, private and public IPM programs have devoted minimal, if any, resources to overcoming control group data problems. This misallocation has had three consequences. First, the development of pest management programs over time has not benefited from performance comparisons between the program and a control group. Second, promoters of pest management programs have had little basis on which to sell the program to farmers. Third, evaluation of pest management programs to aid government policy-makers, the purpose of this report, has been seriously hampered.

Specific Program Evaluations

California Pest Management Consultants

Independent pest management consultants have existed in California since about 1950. Tables 1 and 2 indicate that by 1970 they served 126,100 acres or about 20 percent of the cotton in the San Joaquin Valley. It is estimated that they served 150,000-160,000 acres of cotton in the Valley in 1973 and 190,000-200,000 acres in 1974. While the acreage under the consultants' management has increased, their share of total cotton acreage has declined since total cotton acreage has increased more rapidly in recent years due to high cotton prices. Consultants operate in every county in which cotton is grown. The consultants' shares of total acreage have generally been larger in Kern County (40 percent in 1970) and Fresno County (25 percent in 1970) than in Kings, Madera, Merced, and Tulare counties (3 percent to 11 percent in 1970).

TABLE 1

Consultant Program, San Joaquin Valley, California, 1970-1974

Year	Number of operators				Average size farm	Total in program	Total in cotton in San Joaquin Valley
	With less than 50 acres	With 50-199 acres	With more than 200 acres	Total			
	1	2	3	4	5	6	7
					acres		
1970	54	31	100	185	680	126,100	608,700
1971	55	32	103	190	680	129,200	696,716
1972	a/					132,881	811,347
1973						150,000- 160,000	922,650b/
1974						190,000- 200,000	

a/ Blanks indicate no data available.

b/ Estimated

Sources:

Cols. 1-5: Estimated from a sample of 24 growers over a two-year period representing 12.5 percent of the total acreage under the program.

Col. 6: Data collected from Willey-Norgaard research for Ford Foundation; 1973 and 1974 estimated from a sample of nine consultants and the share of the market they held in 1971-72.

Col. 7: From the County Agricultural Commissioners' Reports.

TABLE 2

Acreage in Consultant Program and Total Cotton Acreage By County San Joaquin Valley, California, 1970-1973

County	1970	1971	1972	1973
	acres			
Kern				
Consultant	67,500	68,400		
Total	170,700	202,700	229,000 a/	258,000
Fresno				
Consultant	42,600	41,900		
Total	167,000	204,416	241,317	279,250
Tulare				
Consultant	7,000	9,200		
Total	118,400	118,000	126,800	135,400
Kings				
Consultant	4,600	4,800		
Total	93,000	109,000	141,000	172,000
Madera				
Consultant	1,100	2,400		
Total	36,800	36,600	41,300	43,000
Merced				
Consultant	2,500	2,500		
Total	23,500	26,000	31,930	35,000 b/
Total consultant	126,100	129,200	132,881	150,000-160,000 b/
Total	609,400	696,716	811,347	922,650

a/ Blanks indicate no data available.

b/ Estimated by author; see Appendix I

Source: Data collected from Wayne R. Z. Willey-Richard B. Norgaard research for the Ford Foundation.

Characteristics of Consultant Users.--Farmers who utilize consultants are generally more experienced in cotton production than those who do not. This characteristic is confirmed by the Willey-Norgaard studies. A second characteristic of the users of pest management consultants is the larger-than-average size of their farms. The vast majority of users have more than 200 acres of cotton. The average cotton acreage is 680 acres--about five times the average of 135 acres for the San Joaquin Valley as a whole.[1/] Table 1 indicates that more than 25 percent of the cotton farmers using consultants have less than 50 acres of cotton. The data fail to indicate, however, that nearly all of these farmers had considerable additional acreage in another crop, typically alfalfa, under the consultants' service. Indeed, the average *total* farm acreage of farmers using consultants on cotton in the Willey-Norgaard study sample was 3,394 acres. A third characteristic of farmers who adopted consultants is that they tend to perceive greater risks from pests and to be more risk averse than farmers who use chemical salesmen. The increased certainty provided by careful field checking, plus the larger number of options open for pest management through the use of natural controls and chemicals when necessary, may be of considerable value to these risk-averse farmers.

Description of Program.--The consultants' pest management program varies from consultant to consultant. The services of some are limited to counting pests while others pay considerable attention to predators, parasites, and

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[1/] The 135-acre average comes from a study by I. R. Starbird and B. L. French, *Costs of Producing Upland Cotton in the United States, 1969*, U. S. Economic Research Service, Agriculture Report No. 277, June, 1972. Table 5 in the above report lists 4,795 farms growing cotton and 643,356 acres in the San Joaquin Valley. The number of farms may include some multiple plots operated by the same owner. Regardless, most cotton is grown on farms larger than 135 acres.

the condition of the crop. More recently, some consultants have adopted the more systematic approaches introduced through the scout program discussed in the following section. A few consultants now emphasize total crop management and provide advice on cultural practices and weed control in addition to pest management. The evaluation of the consultants' performance in this report is based on their average performance in 1970 and 1971.

A key element in the consultants' program is to avoid unnecessary spraying in order to prevent the killing of beneficials and, hence, to prevent subsequent pest population resurgence which would require further spraying. Lygus, the key pest in the San Joaquin Valley, may require treatment early in the season to avoid substantial economic losses. Early treatments, however, can mean early destruction of beneficials and consequent management problems throughout the remainder of the season. Bollworm infestations, in particular, are aggravated by early spraying of lygus. Hence, considerable care is taken to assess the necessity of treatment and to recommend the use of chemicals which are most suitable.

Unlike some extensive field checking programs, the California consultant program has a low ratio of 3-5 scouts per professional entomologist. Each professional typically supervises from 5,000 to 10,000 acres. If the size of fields is large, more acres can be handled. In any case,the acreage per professional is well below the 70,000-100,000 acres per professional of simple field checking programs. As a result of this professional intensity, the consultants almost insist that the grower comply with their recommendations; and the rate of compliance is about 95 percent. Scouts employed by the consultants field check periodically--usually once a week but as frequently as twice a week if pest populations are approaching their economic threshold. The scouts' data are analyzed by the consultant who, in turn, advises the farmer by phone. The consultant personally visits fields and consults with the farmer when the situation in the field is critical, unusual, or the farmer is especially nervous about his pest situation.

Effectiveness of the Consultant's Program.--The consultant's program is biologically effective. There is little evidence to indicate that crop yield is sacrificed under the program and considerable evidence that it is increased. Farmers have generally not been willing to consider reduced yields, and the consultant's reputation suffers from reduced yields. Consequently, sprayings or alternative strategies are recommended by consultants when "true" thresholds are reached. Table 3 indicates that adopters of consultants in 1970 have yields 6 percent larger than a random sample of nonadopters with similar characteristics and 25 percent larger than all producers in the San Joaquin Valley. All yields decreased in 1971 due to insects and poor weather, but consultant users still apparently produced 25 percent more cotton per acre than both the random sample of nonconsultant users or all producers in the Valley. The difference in the value of the yield per acre received by farmers using consultants amounts to $15-$54 in 1970 and $56-$58 in 1971. This difference is substantial and far greater than any possible savings in pest management costs. The difference may be explained by possible reductions in pest damage due to better practices, possible greater plant vitality due to reduced phytotoxicity resulting from pesticides, and possible better crop management stemming from general consultant advice. But it is also very likely that farmers who adopt consultants are better farmers themselves. The relative importance of the possible sources of the increased yield are currently being investigated by Willey and Norgaard.

TABLE 3

Yields, Revenues, and Cost to Cotton Farmers: Adopters and Nonadopters of Pest Management Consultants San Joaquin Valley, California, 1970-71

	1970			1971		
	Adopters	Non-adopters	All	Adopters	Non-adopters	All
	1	2	3	4	5	6
	500-pound bales					
Yield per acre	2.16	2.0	1.73	1.78	1.42	1.41
	dollars					
Price times yield for year[a]	270	255	216	280	224	222
Cost data						
Insecticides and application per acre	6.12	9.34	b/	4.20	15.15	
Consultant's fee per acre	2.68			2.33		
Total insect management costs	8.80	9.34		6.53	15.15	
Herbicide costs	5.35	3.32[c]	3.32[c]	5.49	3.32[c]	3.32[c]
Total pest management costs	14.15	12.67		12.02	18.47	

a/ The 1970 price was 25 cents; the 1971 price was 31.5 cents.

b/ Blanks indicate not applicable.

c/ Willey's nonadopter herbicide data are incomplete; U. S. Economic Research Service data indicate average herbicide costs in San Joaquin Valley were $3.32 per acre in 1969.

Sources:

Cols. 1, 2, 4, and 5:	Data from Wayne Willey's random sample of 24 adopters and 24 nonadopters of pest management consultants.
Cols. 3 and 6:	Data for yield per acre and price times yield from County Agricultural Commissioner's Reports.

The costs of the consultant's advice averaged $2.33 and $2.68 per acre in 1970 and 1971, respectively. Farmers utilizing consultants spent $3.22 per acre less for insecticides and their application than farmers who utilized salesmen in 1970 and $10.95 per acre less in 1971. The net saving for insect management amounted to 89 cents per acre and $8.27 per acre for 1970 and 1971, respectively. For reasons not yet explained, the sample of adopters of consultants spent about $2.00 per acre more on herbicides than did all farmers in the San Joaquin Valley. Because of the additional herbicide use, farmers who used consultants spent $1.48 per acre more in 1970 and only saved $5.45 per acre in 1971 compared to farmers who used salesmen. Over the two-year period, the average cost savings was about $2.00 per acre or about 14 percent of total pest management costs.

The net economic gain of employing a pest management consultant on California cotton depends critically on the portion of the large increase in yield that is attributable to the services of the consultant. If all of the increased yield is attributed to the consultant's services, the farmer received an average net benefit of $38 per acre. This would amount to a substantial increase in net returns due to the services of a consultant who charged about $2.50 per acre. The benefit-cost ratio would be about 8:1. If this is the case, it is very surprising why consultants have difficulty charging what they do for their services or why all farmers have not clamored for their services at that price. But even if none of the increased yield is attributable to the consultants, the farmer saved an average of $7.09 on insecticides and applications at an average cost of $2.50. Thus, the benefit-cost ratio for insect management is at least 2.8:1.

Yield per acre and insecticide expenditures per acre by farm size are presented in Tables 4 and 5. Insecticide expenditures per bale for nonadopters

TABLE 4

Cotton: Average Yield Per Acre
San Joaquin Valley, 1970 and 1971

Cotton acreage	Average yield			
	1970		1971	
	Adopters	Nonadopters	Adopters	Nonadopters
	bales per acre			
0 - 49	1.83	1.98	1.86	1.68
50 - 199	1.73	1.93	1.59	1.98
200 - 999	2.01	2.18	1.79	2.04
1,000 or more	2.28	2.01	1.79	1.22
Average	2.17	2.04	1.79	1.43

Source: Data collected from Wayne R. Z. Willey-Richard B. Norgaard research for the Ford Foundation.

TABLE 5

Cotton: Average Insecticide Expenditures Per Acre
San Joaquin Valley, 1970 and 1971

Cotton acreage	Average insecticide expenditures			
	1970		1971	
	Adopters	Nonadopters	Adopters	Nonadopters
	dollars per acre			
0 - 49	6.53	22.01	13.02	23.24
50 - 199	6.49	13.17	9.02	14.83
200 - 999	9.13	14.10	8.92	13.62
1,000 or more	4.65	7.84	2.79	15.54
Average	6.13	9.34	4.21	15.16

Source: Data collected from Wayne R. Z. Willey-Richard B. Norgaard research for the Ford Foundation.

of consultants generally decrease as farm size increases. In the case of adopters, insecticide expenditures appear to decrease somewhat with increasing farm size; but the relationship was not statistically significant. Aggregated data, which suggest the negative correlation between farm size and insecticide use, are presented in Table 6. Several possible functional forms were investigated. The following fit the nonadopter data reasonably well:

$$\frac{\$\text{ insecticides}}{\text{bale}} = \alpha + \frac{\beta}{\log \text{acres}}.$$

None of the functional forms considered supported the hypothesis that there was a significant relationship between farm size and insecticide use for adopters of consultants.

TABLE 6

Insecticide Costs Per Bale for Adopters and Nonadopters of Cotton Pest Management Consultants in the San Joaquin Valley, California, 1970 and 1971

Acres	1970		1971	
	Adopters	Nonadopters	Adopters	Nonadopters
	dollars			
0- 49	3.98	11.12	6.99	13.85
50-199	3.75	6.83	5.86	7.51
200-999	4.55	6.46	5.00	6.68
1,000 or more	2.04	3.89	1.55	12.75

Source: Data collected from Wayne R. Z. Willey-Richard B. Norgaard research for the Ford Foundation.

Regression coefficients and statistics are presented in Table 7. For nonadopters, the R^2 is reasonably high. The standard errors relative to the coefficients (the T-ratios) indicate that the β terms are significant, and the α terms are less significant. Thus, for nonadopters, there is a strong relationship between insecticide use per bale and farm size. In the case of adopters, the R^2 is very, very low. The T-ratios indicate that the α's are significant, and the β's are insignificant. Thus, for adopters, insecticide use per bale is best described as constant over farm size.

The above findings are consistent with economic theory. Farmers prefer to reduce uncertainty and its associated economic risks. In the case of pest management, uncertainty can be reduced by acquiring an understanding of insect ecology and collecting data on the state of the agroecosystem. A second alternative perceived by farmers is to apply a pesticide in order to "eliminate" the source of the uncertainty, a rational alternative for those farmers with insufficient knowledge of insect ecology to be aware of the problem of resurgence. The first approach requires a substantial fixed investment in knowledge and subsequent information collection with scale economies. The second approach--more frequent pesticide application--has relatively constant costs per acre treatment regardless of farm size. This difference strongly suggests that managers of large farms will find it more advantageous to acquire and practice the principles of pest management than will managers of small farms. This relationship between farm size and pesticide use does not apply to those farmers who have adopted a consultant. The consultants, perhaps irrationally, prefer to collect equally reliable information regardless of farm size even though the cost per acre is greater for small farms.

TABLE 7

Regression Coefficients and Statistics Illustrating Strong Negative Correlation Between Insecticides Per Bale and Farm Size for Nonadopters of Pest Management Consultants San Joaquin Valley, California, 1970-71

$$\frac{\$\ \text{insecticide}}{\text{bale}} = \alpha + \frac{\beta}{\text{log acres}}$$

	Coefficient	Estimate	Standard deviation	T ratio	R^2
Adopters					
1970	α	4.46	1.88	2.37	a/
	β	-1.32	3.81	-0.35	0.006
1971	α	3.74	3.00	1.25	
	β	3.17	6.12	0.52	0.012
Nonadopters					
1970	α	-3.38	3.48	-0.97	
	β	23.92	6.78	3.53	0.437
1971	α	-12.86	8.86	-1.45	
	β	51.38	17.24	2.98	0.357

a/ Blanks indicate not applicable.

Source: Data collected from Willey-Norgaard research for Ford Foundation.

Table 8 indicates the approximate cost breakdown by cost category for consultants' services. Approximately 30 percent of the costs of the consultants' program covers interest and depreciation on capital such as automobiles, laboratory and field equipment, and office space. Another 20 percent covers nonlabor variable expenses such as gasoline and other supplies. Fully 50 percent of the consultant's fee is a return to the labor of the consultant, his scouts, and office help. Approximately half of the return to labor is earned by the consultant himself. The above description is an average for 13 consulting firms involved in cotton and other field crops. Within this set of firms, there is a wide variation in the cost breakdown due to different delivery modes, different crop mixes, different average field sizes and locations, and different levels of efficiency.

TABLE 8

Cost Breakdown for Consultant Program
San Joaquin Valley, California, 1971

Item	Cost per acre
	dollars
Consultant	0.50-0.80
Scouts and other labor	0.45-0.90
Interest and depreciation on capital	0.40-1.00
Gasoline, supplies, and other variable expenses	0.40-0.70
Total costs	1.75-3.40

Source: Based on expenses and revenues of 13 consulting firms primarily involved in cotton and other field crops. The ranges in the various costs reflect differences in average cost per acre between consulting firms due to different delivery modes, different crop mixes, different average field sizes and locations, and different levels of efficiency.

Willey and Norgaard have recently investigated the relationships between consultant firm size, efficiency, economies of scale, and firm characteristics such as management organization, education and experience, and crop specialization. Production models, which assumed all firms were efficient, suggested that there are large economies of scale in pest management consulting. If this is true, we can expect consultants in the future to band together into large firms, administering large acreages. If there are economies of scale, infant industry protection and subsidization policies may be valid to shelter the industry from competition until the scale economies can be realized.

However, a second method of analysis which investigated both efficiency and scale economies indicated that there is a greater range of efficiencies among small firms than large. A comparison of efficient small firms with efficient large firms indicated no economies of scale and perhaps diseconomies of scale. Thus, this analysis indicates that the firms that had grown in size were generally better organized and better run than those which have remained small. Among all firms, efficiency was higher for those firms that were not incorporated and that specialized in a few crops or a crop type. Surprisingly, the past education, experience, and age of the consultant was not significantly correlated with the firms' efficiency. The findings of this second and superior analysis have several predictive and policy implications. First, and contrary to the analysis described in the previous paragraph, consultant firms can be expected to continue to be of mixed sizes. Second, more crops, or at least crop-type specialization, can be expected in the future as the total acreage of all crops in integrated pest management programs increases. Third, average efficiency may be increased and costs reduced significantly in the future if research and Extension programs are directed at increasing the efficiency of pest management delivery through private consultants.

Both the environmental impact and the overall feasibility and constraints of the consultants' program are discussed at the end of the following section on the California scout program due to the similarities between the two.

The California Cotton Scout Program

Description of Programs.--The Extension Service initiated a scout program in the San Joaquin Valley in 1972. Pest management consultants were contracted to supervise scouts and provide advice in conjunction with Extension personnel. A pest management program was designed by Extension entomologists and faculty of the University of California. The major innovation of this IPM program is the systematic monitoring of crop development and the use of economic thresholds for lygus based on a lygus-per-square ratio. Other innovations include improvements in sampling methods and data processing.

Perhaps the most important accomplishment of the program is the development and use of an effective communication device for discussions between consultants and farmers. Weekly updated crop development data and the timing of cultural practices are graphed (Appendix II) and made available to the farmer for each field in the program. Average development data for the county as a whole from the previous year are also included. Crop development progress and setbacks as well as the "normal" path can be quickly reviewed by the farmer. The consultant can show the beneficial or detrimental effect of particular applications of water or fertilizer on square and boll counts and plant height. Farmers have begun to follow and analyze their graphs, to ask sophisticated questions based on their own analysis, and to seek advice concerning cultural practices based on the development history of their crop. The graphs have become a key information marketing device. Private consultants who provide the equivalent of the scout program for farmers without the assistance of the federal subsidy have found the crop development graphs to be an important selling feature.

Systematic and regular data collection requires extra time in the field, nearly twice as much as the normal supervised control program of the independent consultants. In the scout program, data are collected twice weekly throughout the season; whereas in the consultants' normal program, field checks are timed on the basis of pest populations at previous field checks, on weather, and on developments in the vicinity. In the normal program, twice-a-week field checks are the maximum when pests reach critical levels. The increased frequency and regularity plus the greater quantity of data collected has increased the cost of data collection by at least a factor of two. On the other hand, the increased data collection produces a better basis for making pest management decisions, a better basis to assist farmers with cultural practice decisions, and a field data base which should prove extremely valuable for basic pest management and agronomic research. The federal subsidy to this program approximately covers the extra cost of more intensive data collection.

The scout program was started in 1972 on nearly 6,000 acres in Kern County. The program was designed, tested, and modified during this year. The small size, late start, and experimental nature as well as unusually light infestations make 1972 so atypical that evaluation for the purposes of this study is unwarranted.

The program was expanded in 1973 to nearly 19,000 acres--10,415 acres in Kern County, 7,105 acres in Tulare County, and 1,137 acres in Kings County. All cotton farmers were informed of the program's availability, but most participants were recruited directly by county Extension entomologists and consultants. The federally subsidized scout program was not made available to farmers who previously utilized consultants, but data processing and advice were available through Extension for ineligible farmers who were willing to pay consultants extra for the additional data collection of the more sophisticated program. Table 9 indicates that the average acreage in the program per operator was 281 acres in Kern County and 127 acres and 142 acres for Tulare and Kings counties, respectively, in 1973. Whereas 1972 had unusually light infestations, 1973 had heavy infestations. Planting was late due to late spring rains. Early in the growing season, there were outbreaks of beet armyworms, alfalfa loopers, and cabbage loopers. Before these problems had been averted, lygus populations moved into the cotton fields at a high rate for about a month.

The program expanded again in 1974 to 21,615 acres, with 12,170 acres in Kern County, 6,011 acres in Tulare County, 2,995 acres in Kings County, and a total of 700 acres in Fresno and Madera counties. Several large farms were added in Kern and Kings counties; and the average acreage in the program per operator increased to 393 and 214 acres, respectively, in these counties. These average acreages per operator within the program underestimate the average total acreages per operator since many operators did not put all of their cotton acreage into the program and/or grew other crops as well. The importance of total operator acreage and especially individual field size will be discussed later.

The above figures underestimate the impact of the scout program since they only include subsidized acreage officially within the program. According to Hodge Black, Kern County Extension entomologist, four large growers managing 30,000 acres of cotton in Kern County have hired their own pest management personnel who follow scouting program practices. In addition, independent pest management consultants offer services modeled after the scout program to farmers without benefit of the subsidy. In Kern County and probably others, the spillover effect is larger than the official program

TABLE 9

California Scout Program, 1972-1974

	County								
	Kern			Tulare		Kings		Madera	Fresno
	1972	1973	1974	1973	1974	1973	1974	1974	1974
Number of farms									
0-80 acres		3	2	14		0	0	0	0
50-200 acres		15	13	32		7	6	0	2
Over 200 acres		20	16	10		1	8	1	1
Number of operators									
Total	21	37	31	56	46	8	14	1	3
Per average acreage	282	281	393	127	131	142	214	290	137
Total program acreage	5,917	10,415	12,170	7,105	6,011	1,137	2,995	290	410
Total cotton acreage in county	229,000	258,000		135,400		172,000			
Percent of total acreage in program	2.6	4.0		5.2		0.6			

itself and sufficiently large to affect the county average. For this reason the following evaluation based on statistics from the official program and the county average seriously underestimates the impact of the program unless appropriate adjustments are made for the spillover effects. At this time only qualitative adjustments are possible.

In the long run the California scout program will be credited with four less tangible but undoubtedly more important beneficial effects. The first of these is the boost in the adoption of consultants' services due to the introduction of new growers to integrated pest management with the assistance of a temporary subsidy. Probably 20,000 acres of those now in the program would not now be utilizing IPM if there had not been a scout program. Probably about 75 percent, perhaps more, of the acreage will remain under the supervision of a consultant after the federal subsidy is dropped. Thus, an additional 15,000 acres will receive better pest management for years to come. This represents about a 10 percent boost to consultants' acreage overall, or about one year of growth at past rates.

The second important contribution of the scout program is the implementation of a program which stresses total crop management. There is now little doubt in most consultants' minds that in the long run supervised pest control will be superseded by crop management and that the scout program has made a substantial impact on this trend. The third contribution appears to be the introduction of the crop development graph as a communication and marketing device. While this may seem like a superficial advance, both farmers and consultants have found the device to be an important tangible representation of services delivered.

The fourth contribution of the program is in the realm of research. The crop development and pest population data document and lend credence to much of the research undertaken at the University of California during the past decade. More important, these data should be an important base for generating and testing theoretical hypotheses in the future. The data are not as complete as they would be if they were collected by researchers under controlled conditions. On the other hand, the data are more complete, include more observations, and encompass more acres than have ever been collected before. While entomological researchers may prefer controlled experiments, much of the value of the scout data is that they include the normal mistakes made by farmers. The incremental cost of collecting usable data in conjunction with an ongoing management project is small compared to the cost of collecting data independently or conducting experiments for the purpose of generating data.

It is rather discouraging to note that the Extension Service is doing so little to advertise the short-term or long-term benefits of the program. Furthermore, the data to date are inadequately processed for use in basic research, and researchers have shown surprisingly little interest in this valuable data base.

Economic Evaluation.--A major objective of the scout program has been to collect and process pest management data from many farms. Summaries of this data have not been made available for this economic analysis of the program. Extension was unable to process and aggregate the data in time for the author to complete the first draft of this report by the end of the summer of 1974. During that fall, initial aggregate data were provided. Inquiry as to the general nature of the summary led to a subsequent provision of aggregate data which was inconsistent with the first. The combination of the author's detailed analyses of the inconsistencies, Extension's explanation of the inconsistencies, and Extension's unwillingness to cooperate with the evaluation in the first place has led the author to conclude that the data provided are suspect. It is not relied upon in this analysis.

The yields and revenues of participants and nonparticipants in the scout program during 1973 are indicated in Table 10. Participants in the program received lower yields and revenues per acre than growers in their respective counties received on the average. This difference can probably be entirely attributed to the following facts: (1) the scout program was deliberately and properly directed in some cases toward regions where farms had below-average yields; (2) the average farm size in the scout program was smaller than for the county as a whole (Table 4 indicates that large farms had greater yields in 1970); and (3) the average for the county as a whole, especially in the case of Kern County, includes many cotton growers who were already successfully using private consultants and attaining higher yields. Consequently, the lower yields and, hence, revenues of growers in the program probably should not be treated as a cost to the growers in the program.

Pesticide-use information for California is collected by the State Department of Agriculture. However, only those applications made by commercial pest control companies are reported. It has been estimated that 75 percent of the pesticides used on cotton are commercially applied. Hodge Black has processed insecticide usage data for the scouting program in Kern County. His data show that 13,804 pounds of pesticides were applied on 10,500 acres in the program, an average of 1.32 pounds per acre. In 1973, 457,932 pounds of pesticides (excluding herbicides, adjucants, solvents, etc.) were applied to the 258,000 acres of cotton in Kern County.[1/] This means that an average of 1.78 pounds per acre of insecticides was

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[1/] This figure assumes that the state's pesticide-use data represent 75 percent of the actual pesticides used on cotton.

TABLE 10

Returns Per Acre to Cotton Farmers in 1973

Returns	Kern County		Kings County		Tulare County	
	Scout program average	County average	Scout program average	County average	Scout program average	County average
Yield, 500 pound bales	1.74	1.92	1.76	1.82	1.51	1.58
Price x yield for year per acre (dollars)	409.	451.	414.	428.	353.	371.

applied to Kern County cotton. Thus, the average insecticide use in the scouting program was 25 percent less than the average amount used on cotton in the county as a whole. The results of the private consultant's program were more conclusive. The Willey-Norgaard data indicate that the adopters of pest management programs used 58 percent less insecticides than the non-adopters in 1970 and 1971. Based on this information and the proportion of acres in each group, growers who neither used consultants through the scout program nor privately applied an estimated 2.31 pounds of insecticides per acre.[1/] Thus, the scout program resulted in a reduction in insecticide use by 43 percent. Given the nature of this calculation, the actual reduction probably falls between 35 percent and 50 percent.

Data provided by Extension indicate that the cost per acre of delivering the scout program averaged $4.56. Of this, $1.62 was provided by state funds, $0.66 by federal funds, and $2.28 by the grower. The state's contribution is underestimated due to the participation of university researchers and staff and the use of computer facilities. Travel by county farm advisors within the county was at county expense. Some of the travel expenses of the program's director and the economist-statistician are also paid out of other state accounts. These further expenses probably raise the total to $5.50 per

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[1/] An estimated 31 percent of the average in 1973 in Kern County was under the advice of a consultant, 4 percent was in the scout program, an additional 8 percent was under similar management conducted by corporate farm entomologists, leaving 57 percent under the supervision of chemical salesmen. Let I = pounds of insecticide per acre used by growers utilizing salesmen; then,

$$(0.31 \times 0.42\ I) + 0.57\ I + (0.12 \times 1.32) = 1.78$$

where 1.32 and 1.78 are the pounds of insecticide per acre used on acreage within the scout program and for the county as a whole, respectively.

$$I = 2.31.$$

acre. In addition, the participating growers spend more time with scouts and consultants than nonparticipants spend with their chemical salesman. This additional time represents a small additional cost for the grower. Assuming yields and nonpest management costs are the same between scout program participants and users of chemical salesmen, participants on the average have a net savings in pest management costs of from $3.00 to $8.00 per acre, or a private benefit-cost ratio of 2.2 to 4.4. The net social savings are less, between $0.00 and $5.00 due to the public subsidy. The social benefit-cost ratio for the single year may be as low as 1 or as high as 2. Over the long run, the program can be operated by the consultants at somewhat lower costs due to their lesser data needs. The benefit-cost ratio of the 1973 public program is greater than indicated above in that it encouraged growers to adopt integrated pest management sooner. In addition, the foregoing is an underestimate because of the demonstration impact the scout program has had on other growers and because environmental considerations to be discussed subsequently have been ignored.

External Effects and Environmental Impacts.--The deleterious effects on the environment of the use of persistent pesticides is well documented. Concern over these impacts has resulted in restricted use of many chemicals and outright bans on others. The agricultural community's response to these actions has generally been to substitute newer, less-persistent pesticides for the older persistent chemicals. Unfortunately, the use of these "new" chemicals has given rise to new external effects and environmental impacts which were not always anticipated.

For analytical purposes, the external effects of pesticide use by a cotton grower will be grouped into three general classes: (1) effects on other producers, (2) effects on farm workers, and (3) effects on the general environment including wildlife and other nontarget organisms as well as the human population. The substitution of the new chemicals for the old has reduced some of these effects while increasing others. For example, the dangers associated with the accumulation of residuals via biological magnification in man and other organisms have been reduced with the reduction in use of chlorinated hydrocarbons, but the possibility of a "misplaced" application killing large numbers of a particular species has been increased due to the increased use of organophosphates and carbamates. Also, the long-range effects of some of the new chemicals are at present unknown. However, the substitution has, in general, made the nature of the impacts more direct and temporal and, hence, somewhat easier to quantify. Some estimates of these effects are found below.

Although physical measures may be possible, the valuation of external effects is exceedingly difficult. Thus, the procedure adopted herein is as follows. First, pesticide usage by nonparticipants and nonusers will be compared with participants in the scouting program and users of pest consultant services. Insofar as the data permit, this comparison will include a discussion of any noticeable differences in the composition of chemicals used by these groups. Then, given these changes in usage, implications are drawn regarding the changes in external costs and environmental impacts which might reasonably be expected with adoption of IPM programs. When possible, data on external effects are presented. Hopefully, these data will provide the reader with an appreciation of the magnitude of the problem being analyzed.

The analysis is begun with an investigation of the effect of IPM programs on external effects among producers. Since, in general, these effects may be positive or negative among growers and we have no information as to the net effects, it is not possible to draw implications regarding these effects from the fact that pesticide usage is reduced by the IPM programs. It is well known, however, that benefits may be captured if pest management decisions are centralized and if the centralized decision-maker is cognizant of the existing production interdependencies. If these benefits are to be gained, it is essential that the decision-maker has control over all acreage where interdependencies exist. Hence, the scouting program provides an institutional arrangement capable of capturing some of these gains. Likewise, pest consultants with contiguous clients may internalize some of these external effects. In areas where there are large numbers of small farms and several consultants, it is, of course, less likely that interdependencies will be taken into account.

A particular group of producers which might be expected to gain from the reduced pesticide use of IPM is the beekeepers. Beekeeping is a major industry in California. The industry represents a capital investment of $20 million and accounts for 10 percent of the nation's bees at present. In 1971 California crops, with a combined annual income exceeding $300 million, rented more than 300,000 colonies of honeybees for pollination purposes. Over 50 percent of all California bee colonies are located in eight cotton-growing counties.

In 1971 beekeepers filed $190,000 worth of indemnification claims based on estimates of bee losses in the cotton-producing counties. This is 40 percent of the value of the total claims filed for California during that year. Conversations with beekeepers indicate that cotton is one of the crops where bee poisoning is the greatest. Pesticides used in cotton, which are listed as being highly toxic to bees, include Azodrin, Bidrin, Guthion, Methomyl, Methyl Parathion, Parathion, and Carbaryl. The shift from the old to the new chemicals has been particularly disadvantageous to beekeepers.

Firm conclusions as to the net effect of IPM on beekeepers obviously requires a comparison of the composition of total chemical use as well as the amount. Unfortunately, data to make comparisons of this nature were available for only the scouting program in Kern County. There it was found that lesser amounts of Methomyl and larger amounts of Azodrin were used in IPM. Growers in the scouting program used .11 pounds per acre of the two pesticides combined, while those not in the program used .10 pounds per acre. On the surface this suggests that IPM may be increasing bee losses somewhat due to chemicals. A final conclusion, however, must await additional data.

The second major type of external effects analyzed is the effect of pesticide use on farm workers. Losses experienced range from simple discomfort, to lost work time, to accidental death. An indication of the severity of this problem is provided by the figures found in Tables 11 and 12. It is generally accepted that these figures understate the true numbers of poisonings.

Since the data in Tables 11 and 12 do not identify injuries by crop, the numbers of incidents associated with cotton production are not known. Since cotton is not a labor-intensive crop, the amount of occupational illness attributable to pesticides in cotton production is small *vis-à-vis* that found in tree crops, vegetables, and other crops which employ large numbers of seasonal labor.

It is noted, however, that organophosphates were responsible for nearly half of all pesticide injuries (Parathion alone is reported to account for one-third of all organophosphate injuries); and cotton is a major user of these chemicals. Since three-fourths of all pesticide injuries and two-thirds of all organophosphate injuries occurred in eight cotton-producing counties, cotton production undoubtedly accounts for some of these cases. If IPM results in reduced pesticide usage, as is indicated above, and if the chemical

TABLE 11

Occupational Disease Attributed to Pesticides in the Cotton Growing Counties California, 1971

County	Total	Organo-phosphates	Chlorinated hydrocarbons	Herbicides	Other pesticides (includes carbamates, fungicides, sulfur, etc.)
Fresno	88	32	6	18	32
Imperial	46	35	3	3	5
Kern	81	22	8	16	35
Kings	26	8	3	6	9
Madera	7	6	0	0	1
Merced	9	2	0	4	3
Riverside	35	12	3	7	13
Tulare	60	32	0	11	17
Total	352	149	23	65	115

Source: California Department of Public Health, Bureau of Occupational Health and Environmental Epidemiology. "Occupational Disease in California Attributed to Pesticides and Other Agricultural Chemicals, 1971" (Sacramento, 1971).

TABLE 12

Reports of Occupational Disease Attributed to Pesticides
By Industry Group, California, 1971

Pesticides	Total	Agriculture				Manufacturing agricultural chemicals
		Farms	Pest control	Other services	Total agri-culture	
Organophosphates	(221)	(83)	(113)	(1)	(197)	(24)
Parathion	74	46	23	0	69	5
Systox	9	4	3	1	8	1
Thimet	7	5	2	0	7	0
Guthion	4	3	1	0	4	0
Other	127	25	84	0	109	18
Chlorinated hydrocarbons	46	22	13	3	38	8
Herbicides	103	85	9	7	101	2
Carbamates	38	8	26	0	34	4
Sulfur	59	49	8	0	57	2
Total	467	247	169	11	427	40

Source: California Department of Public Health, Bureau of Occupational Health and Environmental Epidemiology, "Occupational Disease in California Attributed to Pesticides and Other Agricultural Chemicals, 1971" (Sacramento, 1971).

composition in terms of toxicity is not significantly different among those used in and those used out of the programs, one would expect these injuries to be reduced significantly by the programs.

One caveat is, however, in order; that is, IPM involves frequent entry of the fields by persons employed to check pest densities. This, in effect, increases the potential for poisonings, *ceteris paribus*. However, field checkers are generally better informed than other farm workers as to (1) the possible harmful effects of the pesticides, (2) when fields have been sprayed, and (3) the types of protective gear necessary. This is in sharp contrast to the situation usually existing with regard to other types of farm labor and to date has resulted in no field-checker poisonings being reported.

Moving on to a discussion of the probable environmental impacts of IPM programs, it is first noted that the general reduction in pesticide usage is expected to reduce both the short- and long-run environmental consequences. Since large residuals of the persistent chemicals from previous applications remain in various environmental mediums, the process of biological magnification will continue for some time. With the shift to the nonpersistent chemicals, however, this process is being slowed. Since the nonpersistent chemicals are, on the average, more toxic, the immediate threat to wildlife populations has been increased. Table 13 lists recorded fish and wildlife losses due to pesticides used in cotton from 1965 to 1969. The data suggest that Azodrin appears to have the most deleterious effects on wildlife. During this same period, the California Department of Fish and Game attributed 757 wildlife deaths to this chemical. Since Azodrin is used almost exclusively on cotton, these wildlife losses are attributed to this crop. In Kern County the scouting program uses on the average 80 percent more Azodrin than the remainder of

TABLE 13

Fish and Wildlife Losses Due to Pesticides Used in Cotton Production, 1965-1969

County	Year	Pesticide	Species killed
Fresno	1965	Azodrin and Dylox	6 pheasants, 1 dove, 2 larks
Madera	1965	Systox	25 jackrabbits
Kern	1965	Kelthane	5 avocet, 2 cinnamon teal
Fresno	1967	Azodrin	55 quail, 1 dove, 6 pheasants
Fresno	1967	DDT and Toxaphene	3 carp (found in canal adjacent to a cotton field treated with Toxaphene)
Imperial	1967	Organic Thiophosphates	300 widgeon
Fresno	1968	Methyl Parathion and Triton	9 ducks
Tulare	1968	Di-Syston	80 finches
Fresno	1968	Parathion	9 ducks
Kings	1968	Azodrin	15 pheasants, 1 hawk
Tulare	1968	Azodrin	6 blackbirds, 2 ducks
Fresno	1968	Azodrin	4 quail, 19 pheasants, 63 blackbirds, 3 doves, 3 larks, 24 sparrows, virginia rail, 1 burrowing owl, 1 killdeer, 1 jackrabbit, 7 wild geese, 3 ducks, 1 hawk

TABLE 13--continued.

County	Year	Pesticide	Species killed
Kern	1968	Azodrin	18 guinea fowl, 29 sparrows, 1 blackbird, 1 hummingbird, 200 turkeys
Madera	1968	Azodrin	134 larks, 1 duck, 3 pheasants, 2 blackbirds
Kings	1968	Herbicide	1,250+ striped bass, 25+ shad
Fresno	1968	Parathion or Toxaphene	35 ducks
Imperial	1968	Azodrin	75+ quail, 26+ mocking birds
Imperial	1968	Herbicide	335 catfish, 11 bass, 147 bullhead, 3 carp
Imperial	1968	DDT and Parathion	25 carp
Fresno	1969	Azodrin	9 pheasants, 3 larks, 1 owl, 3 doves, 26 sparrows, 1 cottontail, 2 blackbirds, 1 hawk
Madera	1969	Azodrin	6 quail

Source: California, Department of Fish and Game, "Fish and Wildlife Losses Due to Pesticides and Pollution From 1965 to 1969," (Sacramento, February, 1970).

the county does. Thus, if these practices are accepted throughout the cotton industry, one might expect an increase in wildlife losses.

In summary, the scouting program and the private pest consultant programs to a lesser degree provide an institutional framework capable of reducing grower-grower external effects. The data suggest that, even though IPM appears to have reduced pesticide usage, some types of external effects--such as effects on beekeepers and wildlife--may have been increased slightly as a result of the difference in classes of chemicals used in these programs. Occupational injuries resulting from pesticide use are expected to be reduced by both the consultants' and the scout programs. The reader is left to draw his own conclusions as to the applicability of these results to the Arizona scouting program.

Long-Run Viability and Technical Expansion Constraints

Though the consultants' program and (eventually) the scout program appear to be viable, four technical factors appear to constrain the expansion of IPM programs. The first of these involves manpower. Experienced consultants are currently quite uncomfortable with how thinly their expertise is spread over less-experienced assistants, newly trained scouts, and nervous farmers.

The second constraint to expansion involves the high cost of field checking and providing advice on small fields. Hodge Black has estimated that the cost of collecting data in the scout program runs as high as $17 an acre for 15-acre fields, declines to $7.00 an acre for a 30-acre field, drops to $3.00 an acre for a 60-acre field, and is as low as $1.30 an acre for a 160-acre field or larger. The field size in the scout program seemed to average between 45 acres and 55 acres in each county. The large differential in cost per field size resulted in considerable negotiating between the consultants and Extension personnel over the appropriate price for services rendered. Price differentiation based on average field size in the various counties, in fact, did result. Quite likely the higher costs for smaller fields also has had some effect in determining which farmers are wooed into an IPM program. While the cost differential, if reflected in prices charged, is great enough to encourage some farmers to reorganize their holdings and plantings, most small fields will continue to exist for some time. General data on the distribution of field sizes do not exist. Typically the largest farms are made up of fields greater than 100 acres, while the medium-sized farms will contain mixtures of large and small fields. Small farms are typically made up of several small fields. Thus, integrated pest management, as it exists to date, is less likely to be practiced on small farms and may not be practiced on medium-sized California farms. This conclusion is borne out by the type of farms that have been recruited by the pest management consultants. Cotton acreage on these farms averaged 680 acres in 1970-71.

These higher costs can be reduced by less intensive and less regular checking of smaller fields. Much of the intensity and regularity of data collection adds little to the quality of decisions though greatly to the value of the data for later research. Nevertheless, small fields are less susceptible to integrated pest management and will be until less expensive methods of monitoring crop development and insect populations can be utilized.

Consultant liability is a third factor which may be limiting the development of integrated control as practiced in California. Consultants can be sued for bad advice or malpractice. But liability insurance offering significant coverage is simply unavailable. The absence of liability insurance deters the weak of heart from joining the industry and discourages banks from lending capital at lower risked rates.

The final technical constraint limits improvements in quality more than the expansion of the existing program. Pest management has developed into crop management; the next logical step is to progress toward agroecosystem management. Such an advance is especially important for San Joaquin cotton since the key pest, lygus, frequently migrates into cotton fields from nearby safflower and alfalfa fields. Lygus control in safflower and alfalfa is considerably less complicated than in cotton, but safflower and alfalfa growers have little interest in controlling lygus unless they also happen to be cotton growers. Thus, as we acquire better understandings of the interrelationships in the agroecosystem, a greater need is seen to increase the sensitivity of our system of management incentives to take into account subtle yet important interdependencies. Growers with considerable contiguous acreage can be advised by consultants in a manner which takes these interdependencies into account. Simple agreements may be possible between adjacent growers. Where fields are small and crops are diversified, the formation of pest management cooperatives or districts may be desirable to carry out truly integrated control.

Information and advertising constraints to the expansion of integrated pest management are discussed in the section on overall feasibility of integrated pest management.

Arizona Pest Management Programs

Arizona has two integrated pest management programs. Our evaluation of these programs is largely a review of articles and reports supplied to us by

Leon Moore, a University of Arizona Extension entomologist.[1] Distance, time, and activities of the summer growing season have prevented the exchange of better information.

Graham County Program.--The Safford area of Graham County, Arizona, has one of the early cooperative pest management programs. Along the Gila River at an elevation of about 2,000 feet is a belt, 2 to 4 miles wide, of irrigated cropland of approximately 38,000 acres. Cotton is grown on 40 to 50 percent of the land, of which 60 percent is the long staple variety. Cotton fields are small, averaging 22 acres in size.

The Safford area has historically had very little problems with pest populations due to its geographical isolation. From 1926 to 1960, the pink bollworm had been the major pest in cotton but had caused little damage. After 1960, pink bollworm populations began increasing at above-normal rates until 1967 when much heavier than usual infestations appeared. Reacting from the heavy losses of that year, the farmers united and formed the pink bollworm committee. The committee's purpose was to protect the 1968 cotton crop by obliterating the pink bollworm. From this came the decision to spray all 13,263 acres of cotton, beginning in early August and continuing at weekly intervals for six weeks with Torbidan--a mixture of Methyl Parathion and Toxaphene. By the end of the season, after 79,758-acre applications of Torbidan at a cost of $220,000, the pink bollworm infestation was controlled. However, the pesticide also inflicted heavy damage to the natural predators; and that same year the cotton perforator, which had always been a secondary pest, became a major pest. At this point the farmers, realizing that something might be going wrong, requested the assistance of the Extension Service and the Department of Entomology of the University of Arizona. A cooperative scouting program was organized. College students and some high school students were recruited and trained in recognizing beneficial and harmful insects. Participating growers' fields were examined weekly, and the results were reported to the farmer who then made the decision to spray his fields or to wait. This program was organized with the participation of the Safford Valley Cotton Growers Cooperative which provided ginning and financial services for the participating growers.

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[1] Lawrence A. Carruth and Leon Moore, "Cotton Scouting and Pesticide Use in Eastern Arizona," Journal of Economic Entomology, Vol. 66, No. 1 (February, 1973).

Leon Moore, M. L. Lindsey, and H. F. Robinson, "An Evaluation of Pesticide Use Practices by Pinal County Pest Management Program Participants, 1973," March 15, 1974 (unpublished).

Neil A. Lawrence and Robert C. Angus, "An Evaluation of Inundative Pest Control Versus Integrated Cotton Pest Management" (unpublished, undated manuscript).

Some data for 1972 were taken from Jasper Womach, "An Evaluation of the USDA Sponsored Cotton Pest Management Program, 1972," U. S. Economic Research Service, Natural Resource Economics Division, July 22, 1974 (unpublished).

Due to lack of a control group, the extent to which field checking produced a reduction in the use of pesticides cannot be determined nor can the net economic benefit of these programs be determined. It can be pointed out that between 1969 and 1971 from 70 to 84 percent of the acres in the program were not sprayed.

Pinal County Program.--The Extension Service initiated a scout program in Pinal County, Arizona, in 1971, with 53 growers and 15,322 acres of cotton which increased to 85 growers and 31,508 acres in 1973 (Table 14). Both growers and Extension Service personnel are involved in the operation of the program. This IPM program monitors crop development though not as thoroughly

TABLE 14

Arizona IPM Programs

	Graham County						Pinal County		
	1969	1970	1971	1972	1973	1974	1971	1972	1973
Number of operators with:									
Less than 50 acres	a/								6
50-200 acres									39
Over 200 acres									40
Total					35		53	60	85
Total acreage in the program	12,750	9,555	11,051		4,492		15,322	18,437	31,508
Total acreage in the county	17,300	15,158	16,610				100,960		
Average farm size in the program							289	307	371

a/ Blanks indicate no data available.

as in the California program. In the Pinal County program, fields are scouted at least once a week. Early in the season, fields are checked every four to five days before the pink bollworm counts are begun. After pink bollworm counts have begun, fields are checked once a week. In 1973 there were 46 scouts and 12 supervisory personnel in the program.

Of the 85 growers participating in the program, 57 adopted the pest management plan of the program, made regular use of the field data, and treated each field according to previously established thresholds. The 28 other participants in the program received the program's recommendations and were informed of insect population levels in their fields but chose their own pest management practices. Pesticide-use data are available for all program participants but not for the 60 to 70 percent of the acreage in Pinal County that was not in the program. The following analysis compares pesticides used by adopters and nonadopters of economic thresholds within the program.

Neither yield nor revenue data for the adopters and the nonadopters of economic thresholds are available, but Leon Moore has stated that the yields were not significantly different given normal variation introduced by differences in soil quality. Over 70 percent of the cotton grades for both groups were strict low-middling and below. The price received for the cotton reportedly was not significantly different between the groups.

In Arizona the bollworm is normally considered a periodic cotton pest; but in 1971 and 1972 there were serious outbreaks. In 1972 infestation levels for the adopter group were apparently slightly higher than the nonadopter group. However, in no case did a mean percentage of boll damage approach the economic threshold level which has experimentally been found to be 15 to 20 percent damaged bolls. The lower infestation levels for the nonadopter group were partially a result of their greater use of pesticides. A higher percentage of infested fields existed in the adopter group. Over the entire growing season, a very small percentage of fields ever exceeded economic levels for either group. Nearly all infested fields ranged in the 0 to 10 percent level of infested bolls. The mean percentage of the bollworm larvae for the adopter and nonadopter groups was very similar. In 1972 damage levels due to lygus were slightly higher for the adopter group. However, the mean percentage of lygus-damaged squares was far below the economic level of 25 percent damaged squares.

Adopters of economic thresholds within the program made 3.4 and 3.6 fewer treatments per acre than nonadopters in 1972 and 1973, respectively. While the adopters tended to substitute higher cost carbamates for less-expensive organochlorine and phosphate insecticides, Table 15 indicates that adopters still realized a net savings on insecticides and their application of $10.61 and $13.98 per acre in 1972 and 1973, respectively. Since both adopters and nonadopters received recommendations and insect count data, it is unclear how these net savings should be interpreted. Table 16 indicates that the per acre costs of scouting were $4.94 in 1972. If this were a privately financed program, the benefit-cost ratio to adopters would be 2.1 in 1972 and about 2.8 in 1973, assuming the nonadopters are a representative control group. Given the federal subsidy, the benefit-cost ratio to adopters was about 25:1 for the two years.

The benefit-cost ratio for the program overall is lower due to the expense of scouting nonadopters' fields which represented 46 percent of the total in 1972 and 20 percent in 1973. Excluding research and education benefits, the social benefit-cost ratio is lowered to 1:2 in 1972 and 2:3 in 1973. The low benefit-cost ratio in 1972 is due to the low rate of adoption. But, clearly, there were educational benefits in 1972 because the rate of adoption increased

TABLE 15

Insecticide Costs of Adopters and Nonadopters of Economic Threshold Practices Cotton Scout Program, Pinal County, Arizona, 1972 and 1973

	1972		1973	
	Adopters	Nonadopters	Adopters	Nonadopters
Acres treated	8,620	9,495	24,145	3,616
Acres not treated	95	0	982	0
Total acre treatments	64,893	102,693	115,221	29,781
Treatments per acre	7.4	10.8	4.6	8.2
	dollars			
Insecticide and application cost per acre treatment	4.17	3.84	4.77	4.38
Total insecticide and application cost per acre	30.86	41.47	21.94	35.92

Sources:

Leon Moore, M. L. Lindsey, and H. F. Robinson, "An Evaluation of Pesticide Use Practices by Pinal County Cotton Pest Management Program Participants, 1973," March 15, 1974 (unpublished).

Cost estimates for 1972 based on Neil A. Lawrence and Robert C. Angus, "An Evaluation of Inundative Pest Control Versus Integrated Cotton Pest Management" (unpublished). These were inflated for 1973 according to the proportions suggested by Moore, Lindsey, and Robinson, op. cit., Table 1.

TABLE 15

Cost Breakdown for All Participants, Cotton Scout Program
Pinal County, Arizona, 1972

	Cost per acre	Total cost	Source of funds		
			Farmer	State	Federal
	dollars				
Scouts[a]	1.44	40,200	[b]		
Supervisors[a]	0.88	24,750			
Professional[a]	1.96	55,000			
Overhead[c]	0.65	18,300			
Total scouting costs	4.94	138,250	13,200[d]	30,000	95,050
Insecticide and application costs	35.86	1,004,136[e]	1,004,136		
Total pest management costs	40.80	1,142,386	1,017,336	30,000	95,050

a/ Includes salary and expenses such as transportation.

b/ Individual classes of expenditures are not divided by source of finding.

c/ Clerical, $5,400; supplies, $5,700; and computer, $7,200.

d/ This is equivalent to 47 cents per acre.

e/ An average of 8.6 applications were made on all 28,000 acres. Pesticide costs averaged $2.92 per acre treatment, and application costs are estimated at $1.25 per acre treatment.

Source: Jasper Womach "An Evaluation of the USDA Sponsored Cotton Pest Management Program," 1972, U. S. Economic Research Service, Natural Resource Economics Division, Tables 1, 4, 8, and 15, July 22, 1974, pp. 11, 13, 14, 18, and 25 (unpublished).

from 46 percent to 80 percent in 1973. The benefit-cost ratio for the federal program over the long run is the discounted savings of adopters every year in the future divided by the discounted program costs. Over the long run, this ratio will probably approach 3:1 due to higher rates of adoption, increased savings due to the extra resistance that would have occurred, and program improvements that are lowering scouting costs.

Besides all of the other problems associated with control groups discussed in the introduction to this report, the nonadopters in the Arizona program received valuable information. However, for reasons unknown to us, they did not choose to follow the recommended practices at all or at least diligently enough to be classified as an adopter. If this information reduced the insecticide use of nonadopters at all during the year in which they were so classified, then the above benefit-cost ratios are underestimates of the true ratio, assuming the nonadopters were representative of farmers generally. This latter assumption is subject to all of the arguments given earlier in the introduction.

Overall Feasibility of Integrated Pest Management in California and Arizona

This report documents the effectiveness of integrated pest management programs as currently practiced in California and Arizona. While the evaluation suffers from poor and inappropriate data, even the conservative estimates of the net gains from utilizing integrated control appear to be positive and significant. Opportunities for farmers to adopt IPM through the use of consultants have existed for many years. Yet, IPM, though gradually gaining acceptance, has not taken hold nearly as rapidly as either its private or public advantages suggest it should. Given current trends and programs, perhaps 80 percent of the larger growers representing perhaps 75 percent of all acreage in the San Joaquin Valley will adopt IPM in the next decade. Hopefully, some effort can be directed at increasing the rate of adoption and at reducing the cost of delivery to small fields.

The economic advantages of hiring a consultant or adopting integrated control have not been adequately demonstrated or advertised by any public agency in California even though such promotion can readily be justified in terms of health, safety, and environmental quality. Quite the contrary, evaluation and promotion have been avoided. The Extension Service has not yet documented the effectiveness or failings of integrated pest management. Extension economists have been aware of the research on the consultant industry by Willey and Norgaard for several years but to date have shown no interest in putting it into a form that would be meaningful to farmers or more helpful to policymakers. The Annual Report for the 1973 California scout program notes bravely under the subtitle, "Accomplishment and Evaluation" (page 8), "some growers indicate they are making fewer insecticide and miticide applications than they were prior to their involvement in the program." Unlike California, Arizona has made serious attempts to evaluate the economic advantages of the Graham and Pinal counties' programs and to disseminate this information in its Annual Report and in journals.

Pest management involves decision making under uncertainty. Integrated pest management reduces uncertainty through information collection and superior analysis. Risk-averse farmers find risk reduction inherently desirable. Given the hesitancy on the part of public agencies to promote IPM or even to simply document its good and bad features in other than biological terms, most farmers may conceive that IPM programs are more rather than less risky than following a chemical salesman's advice. At this stage, appropriate advertising and marketing strategies will have to counteract the psychological effect of past inaction.

This report documents that in all programs the cost per acre of delivering IPM to small fields is considerably higher than for large fields. In the California scout program, the total cost of data collection and analysis and delivery to the farmer is roughly the same for a 16-acre field as for a 160-acre field. For the 16-acre field, in the California program the approximate $16-per-acre delivery cost exceeds all possible savings in insecticide cost. Possible increases in yields may still make the program viable on the small fields but not nearly as attractive as on the larger fields. Data collection methods can be compromised on smaller plots to reduce costs. Perhaps travel costs can be reduced by training farmers with only a few small fields to collect crucial data themselves and phone it into a supervising entomologist. Ultimately, pheromone and other trapping techniques may be improved to assist farmers or pest management supervisors with small fields. This problem will be eased in the long run as the efficiency of the consultants increases through experience and as the extent of their travels is reduced as more nearby farmers join the program and new consultants acquire the older consultants' more distant acreage. Nevertheless, research should be directed toward reducing delivery costs, especially on smaller fields.

Promotional neglect and high delivery costs for small fields appear to be the only constraints on the overall feasibility of integrated pest management in California. In Arizona the costs of delivery to small fields are apparently also considerably higher; but, at least, in Graham and Pinal counties, the economic significance of integrated pest control has been evaluated and made known.

Applicability of Findings of Other Crops

The biological aspects of IPM on cotton are nearly unique; hence, there is little reason to expect that the biological success of IPM on cotton can be related to other crops. This report, on the other hand, has been more concerned with IPM delivery mechanisms than biological relationships. Regardless of the crop type, IPM typically involves extensive monitoring of pest population and plant development. To the extent that these populations and plant characteristics are fairly uniform over large areas, the cost of field checking with current methods will be considerably greater for small fields than large ones. This problem will typically be of less importance on intensively managed crops, such as vegetables or citrus, since the potential pesticide savings per acre through IPM is relatively much higher.

IPM programs on other crops also suffer from promotional neglect in California. The benefits and costs of all IPM programs remain to be documented appropriately in California. This critique applies to the pear scout program as well.

In both California and Arizona, independent pest management consultants provide integrated pest control programs of varying degrees of sophistication in other crops. In the San Joaquin and Sacramento valleys, nearly every crop is served by at least one consultant somewhere. The continued existence of independent consultants attests to the viability of the basic concepts of integrated pest management in many crops.

APPENDIX I

Projections of Acreage Under Pest Management Control in the San Joaquin Valley for 1973

The Willey-Norgaard data base uses the cotton acreage in California under pest management control for 1970-1972. In order to update this information, questionnaires were mailed to pest management consultants requesting the acreage by county under their management for 1973 and 1974. Of the 20 consulting firms in cotton, 9 replies were received representing 49 percent of the 1972 acreage. It is assumed that the total acreage under consultant supervision increased by the same percentage from 1972 to 1973 as did the acreage under management by the respondents during this period. In 1972 the responding consultants had 69,127 acres under their supervision. This increased to 78,066 acres in 1973, an increase of 12.9 percent. If we assume the respondents represented a random sample, then the total cotton acreage under pest management supervision would have increased by 12.9 percent between 1972 and 1973. In 1972 there was a total of 139,000 acres under pest management supervision in the San Joaquin Valley. Assuming the 12.9 percent increase in 1973, then there would have been a total of 157,000 acres under pest management control in the San Joaquin Valley in 1973.

Between 1973 and 1974, the respondents' acreage increased from 78,066 to 96,359 acres, an increase of 23.4 percent. Extrapolating this increase to the entire San Joaquin Valley, the cotton consultant industry puts the total acreage at 193,800. For the text, the estimate is given as 150,000 to 160,000 acres for 1973 and 190,000 to 200,000 acres for 1974.

APPENDIX II

California Cotton Pest Management Program, 1974
Field Inspection and Reporting Techniques

V. E. Burton, Extension Entomologist

The procedures outlined will be used by all field checkers working in the cooperative USDA-UCCE Cotton Pest Management Program. These procedures are subject to change during the production season, but changes will be made only following discussion with all supervising entomologists and field checkers.

Methods will be outlined and demonstrated by Cooperative Extension personnel at the beginning of the season. Additional training sessions will be held for field checkers as necessary.

I. Field Inspection

A. Visually divide each field or groups of small fields into four equal quadrants.

B. Make one plant growth analysis and one complete insect and spider mite population evaluation in each of the four quadrants.

C. A second inspection of each field will be made each week three or four days following the previous inspection. The second inspection will be made in the previously described manner but will consist of a count of lygus and/or bollworms, depending upon the time of season and instructions from the supervising entomologist.

D. Each field checker, supervising entomologist, and UCCE representative is expected to submit a field inspection report each time he visits a field.

E. All identifiable cultural practices in each field and significant adjacent habitat changes will be recorded as outlined whenever they are observed.

F. Contracting supervising entomologists will be responsible for early season pest population surveillance and, in cooperation with UCCE personnel, make recommendations for treatment where warranted.

II. Report Forms

The forms used in 1973 will be used during the early part of the 1974 season. Sometime in June a single new form will be available. There are four sheets (copies) for each form. After a form is made out, the supervising entomologist and his checkers are responsible for leaving a copy of the report with the grower. Two copies will be left at the cotton gin--one of these copies to be retained by the farm advisor and the other to be forwarded to the computer center. The fourth copy is for the supervising entomologist.

A. Report Identification

The first line of blanks at the top of the form is very important because these blanks are used to identify the individual fields.

1. County

The appropriate county identification number should be entered in this blank throughout the season: Kern, 15; Kings, 16; Tulare, 54; Fresno, 10; Madera, 20; and Merced, 24.

2. Checker I.D.

Each person inspecting fields in the program will be assigned a number which he will use all season. The following number ranges will be used: University personnel, 1-9; Nickelsen, 11-19; Seaton, 21-29; Sampson, 31-39; Prentice, 41-49; Gordon, 51-59; Clevenger, 61-69; Grassel, 71-79; Muller, 81-89; and Michaels, 91-95. Where supervisors or field checkers are working in the project for a second or third year, use the same number as used previously.

3. Field I.D.

Each grower will be assigned a number and each of that grower's fields will be numbered. The field checker must know the grower and field identification numbers to enter them properly. For example, grower number 2 may have three fields in the program. The Field I.D. would be filled in as 2-1, 2-2, and 2-3 for each field report. If a grower has but one field in the program, only the grower number has to be entered.

4. Producer

Enter the grower's name.

5. Date

Use numbers for month and day, thus 6-3 means June 3, 1974.

6. Time

Use military time; thus, 1030 means 10:30 a.m., while 1400 means 2:00 p.m. and 1630 means 4:30 p.m.

7. Producer Field I.D.

In some cases a grower may identify his fields in a specific way which we are not using. Enter his identification here if it helps the grower tie a report to a specific field; thus, you might use "SW lease," "Bank America 40," "home place," etc.

8. Recommendation

   Supervising entomologists will fill in this information. Field checkers do not make recommendations.

B. Field Inspection Information

1. Pest and beneficial insect species are coded on this form so that two letters can be entered at the top of a column to indicate the species being recorded. For example, in the column "LA," you would enter the number of lygus adults taken in a sample while the number of nymphs taken would be entered under the column "LN." If 15 lygus samples were taken, LA and LN would be entered as column headings in the adjacent columns. If more species are counted than columns available, use a second report form.

2. Sample location. As described earlier, you will visually divide each field into quadrants. Each quadrant is identified on the form, i.e., NW 1, NE 2, SE 3, SW 4, etc. Be consistent. Record all inspection information from the northwest quadrant under NW 1 or NW 5. For plant growth analysis, record in a similar manner.

3. In recording insect or fruit counts, a blank in a square means that you did not inspect for that insect or count squares, etc. Where an inspection is made and no individuals are found, enter a "0." For example, if no *Orius* (minute pirate bugs) were found in a sample or series of samples, it should be recorded as shown:

0

C. Crop History Information

1. The legal description of a field, acreage, variety, planting date and planting pattern are once-a-year entries. This information, together with preplant fumigation, herbicide, or systemic insecticide use, should be submitted as soon as possible. Use the 1973 Crop History Form for submitting this information.

2. Field checkers, with grower assistance, should record cultural practice activities as accurately as possible throughout the season.

3. Pesticide use should be recorded at the time a material is used. Where only a portion of a field is treated, this should be noted (bordering for control of spider mites, for example). Otherwise, it is assumed that the entire field was treated.

4. Plant damage due to disease, weather conditions, pesticide burn, etc., should be recorded when observed.

5. Adjacent habitat--alfalfa, cotton, orchard, etc.--should be recorded. If grain is harvested or alfalfa cut, this information should be noted.

6. Yield is a once-a-year entry obtained by the supervising entomologist and/or farm advisor.

III. Pest Species

A. Lygus

1. Counts will be taken twice weekly at three- to four-day intervals, beginning with squaring in June and continuing as long as the lygus is a potential problem.

2. A sample will consist of 25 sweeps down a single row of cotton. A sweep is one pass of the insect net through the top of a cotton plant in a manner which slaps the top 6 to 8 inches of the plant into the net.

3. A minimum of four samples will be taken at each inspection. Where counts are running in the range of 7 to 10 per 50 sweeps, counting each nymph as 2, additional samples should be taken. Only actual number of adults and nymphs found in a sample are entered on the inspection report. You must compute the number of lygus per 50 sweeps and the lygus to square ratio from these counts.

4. The lygus-to-square ratio =

$$\frac{\text{average lygus per 50 sweeps per week}}{\text{number of squares per 1/1,000 acre}} \times 100{,}000.$$

B. Bollworm

1. Population counts will be taken when bollworms begin to appear in the fields. This may occur as early as late July. In all probability, one lygus evaluation will be dropped when bollworm counts are initiated. At a later date, the lygus evaluation will be dropped, and two bollworm inspections will be made.

2. For evaluation of bollworm populations, the following methods should be followed:

   a. Two bollworm inspections should be made each week beginning in mid-August or earlier if the lygus is no longer a threat in the field.

   b. All plant growth types occurring in a field should be sampled (both short and rank growing areas). This is the same as the approach used for sampling lygus populations and plant growth analysis.

   c. Inspect the top half of all plants in the area used in the plant growth analysis count. This means that once per week, the same sample area and plants will be used for bollworm, square, flower, boll, main-stem node, and plant counts and plant height readings. When two bollworm counts are made each week, one count will involve recording only the number of large and small worms found in the sample area plus the number of plants in the sample area. From this information, it will be possible to compute the worm count to number of worms per 100 plants.

d. Inspect only the top half of the plant for bollworms. When inspecting a plant, carefully check the tender terminal growth, squares, flowers (white, pink, and dried) and bolls.

e. Record the number of small worms (less than one-half inch in length) and large worms (over one-half inch in length) found in each sample area.

f. As with sampling for lygus, it is desirable to take more than four samples per field if the population is approaching the treatable level of 20 small worms per 100 plants.

g. Before recommending an insecticide treatment for bollworm control, check with either the farm advisor involved in the project area or Charles Gallagher.

C. Spider Mites

1. While making lygus and bollworm evaluations, the field checker should observe the field for spider mite infestations. Particular attention should be given to the edges of the field since infestations frequently develop first along fence rows and next to roads.

2. Infestations are rated as none, light, medium, or heavy.

D. Aphids

1. Aphid infestations are most common in early season (seedling stage) and again late in the season when the bolls are open. Infestations are found as widely separated "islands" of infested plants, particularly in late season.

2. Infestations are rated as none, light, medium, or heavy.

E. Other Potentially Damaging Species

1. Western yellow striped armyworm, beet armyworm, cabbage looper, salt marsh caterpillar and stinkbugs are species that may be encountered. Indications of developing infestations will be seen in sweep samples and/or while making bollworm inspections. Counts will be made only when significant populations develop. Detailed sampling procedures will be outlined when and where problems are encountered.

2. When any of these species are encountered, notation should be made on the reporting form.

IV. Beneficial Species

A. Counts will be taken weekly throughout the season beginning at the time lygus counts are initiated.

B. Sampling will follow procedures 2 and 3 as given for the lygus.

C. Pyrethrum-type aerosols will be provided upon request enabling the the checker to take a 25-sweep sample, knock all of the insects out with a shot of aerosol material, and count the beneficials taken in the sample. A lygus count can be made from the same sample.

D. Lacewings will be counted and recorded as adults and larvae. All other species will be recorded as a single count. Thus, for big-eyed bugs, if 5 adults and 3 nymphs are found in a sample, the figure "8" would be entered in the appropriate column of the report. Other species such as damsel bugs and minute pirate bugs will be recorded in a similar manner.

V. Plant Growth Analysis

A. Proceed to near the center of each field quadrant as outlined above. Throw the insect net in any direction so as to randomly select a sample site. The plant growth analysis will be made where the net falls providing there are plants in the row (avoid large skips).

B. An area of 1/1,000 of an acre will be counted in each field. This area will be divided into four equal sample areas, one sample area per field quadrant. In fields having a 38-inch row spacing, each sample area will be 41 inches long. In fields having a 40-inch row spacing, each sample area will be 39 inches long.

C. The prescribed number of row feet to be counted will be marked on the ground. Count the number of plants within the marked-off area. Record the number of main-stem nodes and the height of the tallest plant in the sample area. Count all squares, flowers, small bolls and large bolls on the plants within the sample area. Do not count fruiting forms on branches that come into the sample area from plants outside of the sample area.

D. Boll size. During 1974, boll counts will separate small and large bolls. Small bolls include purple flowers and bolls which are not yet protruding above the bracts. Large bolls include all bolls from the time they are apparent above the bracts through mature bolls.

Appendix D-i

EVALUATION OF
PEST MANAGEMENT PROGRAMS
FOR COTTON IN TEXAS

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J. E. Casey

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R. D. Lacewell
J. E. Casey

June 1975

Table of Contents

Page

Acknowledgements ii

Introduction D-1

Major Programs D-3

I. High Plains Program D-6

  Program Characteristics D-6

  Users and Location D-7

  Assessment D-9
    Biological effectiveness D-9
      Weevil populations D-9
      Yield implications D-12
    Costs and returns D-12
      Implementation D-13
      Annual overhead D-13
      Operation D-14
      Producer D-16
    Environmental implications D-18

  Program Feasibility and Expansion D-21

II. Glasscock County D-23

  Program Characteristics D-23

  Users and Location D-24

  Assessment D-26

Page

Biological effectiveness D-26
Costs and returns D-27
Implementation D-27
Operation D-28
Producer D-31
Environmental implications D-31

Program Feasibility and Expansion D-33

III. South Texas Program D-34

Program Characteristics. D-35
General. D-35
Traditional production D-35
Narrow row-short season D-35
Insect control D-36
Traditional D-37
Narrow row-short season D-37

Users and Location D-39

Assessment D-40
Biological effectiveness D-40
Costs and returns D-41
Environmental implications D-42

Program Feasibility and Expansion D-44

IV. Pecos Program D-45

Program Characteristics D-45

Users and Location D-47

Assessment D-47
Biological effectiveness D-48
Costs and returns D-52
Environmental implications D-54

Program Feasibility and Expansion D-54

V. East Texas Program D-56

Program Characteristics D-56

Users and Location D-57

Page

Assessment . . . D-59
  Biological effectiveness . . . D-59
  Costs and returns . . . D-61
    Program costs . . . D-62
    Producer . . . D-62
  Environmental Implications . . . D-64

Program Feasibility and Expansion . . . D-67

Texas Cotton Insect Management Program . . . D-72

I. Rio Grande Valley Program . . . D-76

Program Characteristics . . . D-77

Users and Location . . . D-78

Assessment -- 1972 . . . D-80
  Biological effectiveness . . . D-81
  Costs and returns . . . D-82
    Implementation . . . D-82
    Program costs . . . D-83
    Producer . . . D-84
  Environmental implications . . . D-84
  Participating growers evaluation . . . D-86

Assessment -- 1973 . . . D-88
  Biological effectiveness . . . D-89
  Costs and returns . . . D-90
    Program costs . . . D-90
    Producer . . . D-90
  Environmental implications . . . D-92
  Participating grower evaluation . . . D-95

Program Feasibility and Expansion . . . D-97

II. Blacklands Program . . . D-99

Program Characteristics . . . D-100

Users and Location . . . D-101

Assessment -- 1972 . . . D-103
  Biological effectiveness . . . D-103
  Costs and returns . . . D-104
    Implementation . . . D-104
    Program costs . . . D-105
    Producer . . . D-105

Page

Environmental implications D-105
Participating grower evaluation D-107

Assessment -- 1973 . . . . D-108
Biological effectiveness D-108
Costs and returns D-109
Program cost D-110
Producer D-110
Environmental implications D-113
Participating grower evaluation D-114

Program Feasibility and Expansion D-117

III. Trans-Pecos Program D-120

Program Characteristics D-121

Users and Location D-123

Assessment -- 1972 . . . . D-124
Biological effectiveness D-124
Costs and returns D-125
Implementation D-125
Program costs. D-125
Producer D-128
Environmental implications D-128
Participating grower evaluation D-129

Assessment -- 1973 . . . . D-130
Biological effectiveness D-130
Costs and returns. D-131
Program costs. D-131
Producer D-133
Environmental implications D-135
Participating growers evaluation D-136

Program Feasibility and Expansion D-138

IV. Frio County Program D-141

Program Characteristics. D-141

Users and Location D-144

Assessment -- 1972 . . . . D-144

Page

Biological effectiveness D-145
Costs and returns. D-147
Implementation D-147
Program costs D-147
Producer D-150
Environmental implications D-150
Producer contact D-151

Assessment -- 1973 . . . . D-151
Biological effectiveness D-152
Costs and returns D-153
Program costs D-153
Producer D-155
Environmental implications D-157
Education D-158

Program Feasibility and Expansion D-159

V. Total Texas Cotton Insect Management Program Cost D-162

Implementation. D-162
Implementation -- State coordination D-162
Implementation -- State total D-164

Operation D-164
1972 Operation -- State coordination D-164
1972 Operation -- State total D-166
1973 Operation -- State coordination D-169
1973 Operation -- State total D-171

Overall Feasibility D-173

I. Diapause Boll Weevil Control Programs D-173

II. Overall Management Programs D-177

III. Insect Management Program D-182

Cost Effectiveness D-182

Biological and Environmental Effectiveness D-187

Program Feasibility D-189

IV. Feasibility of Integrated Pest Management Programs D-190

Table of Contents Concluded

Page

Components of a Successful Program D-190

Role of Government Support D-191

Future Direction of Integrated Pest Management D-194

Expansion to Other Cro D-196

References D-200

List of Tables

		Page
Table D-1	Cotton acreage treated under the Texas High Plains reproductive-diapause boll weevil control program . .	D-8
Table D-2	Estimated percent reduction in potential overwintering weevil population due to the High Plains reproductive-diapause program, 1964-1973	D-10
Table D-3	Overwintering boll weevil populations in overwintering habitat	D-11
Table D-4	Estimated annual overhead costs associated with the High Plains reproductive-diapause boll weevil control program	D-14
Table D-5	Operation costs of the Texas High Plains reproductive-diapause boll weevil control program, 1964-1973	D-15
Table D-6	A comparison of expected cotton production costs with and without the High Plains reproductive-diapause program, 1972 basis	D-17
Table D-7	Quantity and insecticide used for the Texas High Plains reproductive-diapause boll weevil program 1964-1973	D-19
Table D-8	A comparison of expected insecticide use with and without the High Plains reproductive-diapause boll weevil control program	D-20
Table D-9	Cotton acreage treated under the Glasscock diapause boll weevil control program	D-25
Table D-10	Man days used for operation of the Glasscock County diapause boll weevil program	D-29
Table D-11	Diapause chemical and application costs and estimated overhead for the Glasscock County diapause boll weevil control program	D-30
Table D-12	Average per acre insect control costs of cotton production in Glasscock County and effect of a diapause boll weevil control program	D-32

Page

Table D-13 Expected pounds of insecticide use for two cotton production practices in the Texas Rio Grande Valley D-36

Table D-14 Total acres of cotton produced by county in the Texas Rio Grande Valley in 1973 . . . . D-39

Table D-15 A comparison of expected costs and returns for two cotton production systems in the Rio Grande Valley D-42

Table D-16 A comparison of number of insecticide applications and insect control cost at the Pecos Research and Extension Center and the surrounding counties: Reeves and Pecos Counties D-49

Table D-17 A comparison of yield on the Pecos Research and Extension Center and in surrounding counties of Pecos and Reeves County D-51

Table D-18 Expected reduction in insect control costs through the adoption of an integrated pest management program in Pecos and Reeves Counties, Texas: 1968-73 . . . . D-53

Table D-19 Acres of cotton produced by the Texas Department of Corrections, 1968-1972 . . . . D-58

Table D-20 Expected per acre costs and returns associated with cotton production using traditional pest control techniques and an IPM program and in Trinity River Area and Brazos River Area D-63

Table D-21 A comparison of chemicals applied with traditional practices and an IPM program: Trinity River area section of the Texas Department of Corrections cotton farms. D-65

Table D-22 A comparison of chemicals applied with traditional practices and an IPM program, Brazos River area section of the Texas Department of Corrections cotton farms. D-66

Table D-23 Estimated insecticide use with the IPM program and traditional insect control technique in the Brazos River area D-68

Page

Table D-24 Estimated insecticide use with the IPM program and traditional insect control technique in the Trinity River area D-69

Table D-25 Distribution of a sample of participating and non-participating cotton producers by acres of cotton produced, Rio Grande Valley, 1973 . . . . D-79

Table D-26 Distribution of farms size by acres produced in the Rio Grande Valley D-81

Table D-27 Estimated implementation costs of the Rio Grande Valley Scout Program D-83

Table D-28 Rio Grande Valley program cost by source of funds, 1972 . . . . D-85

Table D-29 Rio Grande Valley program cost by source of funds, 1973 . . . . D-91

Table D-30 A comparison of expected per acre costs and returns for participating and non-participating irrigated cotton producers in the Rio Grande Valley Program, 1973 . . . . D-93

Table D-31 Distribution of a sample of participating and non-participating cotton producers by acres of cotton produced, Blacklands, 1973 . . . . D-102

Table D-32 Estimated implementation costs of the Blacklands Scout Program D-104

Table D-33 Blacklands program costs by source of funds, 1972 . . . . D-106

Table D-34 Blacklands program costs by source of funds, 1973 . . . . D-111

Table D-35 A comparison of expected per acre costs and returns for participating and non-participating cotton producers in the Blacklands program, 1973 . . . . . D-112

Table D-36 Distribution of a sample of participating and non-participating cotton producers by acres of cotton produced, Trans-Pecos, 1973 . . . . D-124

Page

Table D-37 Estimated implementation costs of the Trans-Pecos Scout Program D-126

Table D-38 Trans-Pecos Program cost by source of funds, 1972. . . . . D-127

Table D-39 Trans-Pecos Program cost by source of funds, 1973. . . . . D-132

Table D-40 A comparison of expected per acre costs and returns for participating cotton producers in Trans-Pecos Program, 1973 . . . . D-134

Table D-41 Estimated implementation costs of the Frio County Program D-148

Table D-42 Frio County Program cost by source of funds, 1972. . . . . D-149

Table D-43 Frio County Program costs by source of funds, 1973. . . . . D-154

Table D-44 A comparison of expected per acre costs and returns for participating and non-participating cotton producers in the Frio County Program, 1973 . . . . . D-156

Table D-45 A comparison of insecticide applications of participants and non-participants in Frio County, 1973 . . . . D-158

Table D-46. Estimated implementation costs of the Texas cotton insect management program incurred at the state level D-163

Table D-47 Estimated implementation costs of the Texas cotton insect management program -- Texas total . . . D-165

Table D-48 State coordination cost of the Texas insect management program by source of funds, 1972 . . . . . D-167

Table D-49 Texas cotton insect management program cost by source of funds, 1972 . . . . D-168

Table D-50 State coordination cost of the Texas cotton insect management program by source of funds, 1972. . . . . D-170

Page

Table D-51 Texas cotton insect management program cost by source of funds, 1973 . . . . D-172

Table D-52 Cost per pound of lint produced for a sample of insect management program participants and non-participants, Texas 1973 . . . . D-185

INTRODUCTION

Much attention has been directed recently to integrated pest management (IPM) strategies in response to a producer's desire to reduce production costs and the general concern for the environment. Integrated control, as identified by Adkisson, is a pest management system that uses all suitable methods in as compatible a manner as possible and maintains pest populations at levels below that causing economic injury (Adkisson and Haney). The components used in an IPM program are designed to exert maximum suppression of the pest population without creating great imbalances in the agroecosystem.

A great deal of the efforts to develop IPM strategies has been on cotton since more insecticide is used annually on cotton than any other single crop in the U.S. With the effort and funds that have been expended on IPM strategies for cotton, it is appropriate to review in one report, strategies that have or can be adopted by producers. This report is limited to cotton production in Texas and feasible IPM strategies that are available.

This report is based on several research reports and interviews and on experience of the authors in evaluating IPM strategies. Research on which this report is based was conducted principally by U.S. Department of Agriculture, Texas Agricultural Experiment Station and Texas Agricultural Extension Service and either supported internally or in part by contract funds provided by the U.S. Department of Agriculture, Environmental Protection Agency, National Science Foundation and Council on Environmental

Quality. Therefore, this report is not original research but rather the identification of basic characteristics of IPM strategies as quantified in the above research.

Although this report is limited to IPM strategies for cotton production in Texas, several different and separate production regions are included. Average annual rainfall varies from over 45 inches in the eastern part of the state to less than 12 inches in the Pecos (Texas Almanac). The typical growing season ranges from 330 days in the Lower Rio Grande Valley to 208 days in the Southern High Plains of Texas (Texas Almanac). With the extreme variation in climatic, geographic and agronomic characteristics of the different production areas, Texas contains a representation of many different types of cotton production areas that exist throughout the U.S.

The organization of this report is to initially identify major components of IPM programs for Texas in aggregate and then specify the major IPM programs. The specific programs, although they contain basically the same components, are construed differently by major cotton production area to conform best to regional production characteristics. Therefore, by necessity, the assessment of each IPM program relates to the region for which it was developed.

The discussion of IPM programs for cotton in Texas is also limited to operational programs. This means the highly sophisticated IPM programs in various stages of development where little or no testing has occurred are not included. Among these is the work currently underway in systems model building. The systems modeling appears most promising and relationships are identified which influence and improved current operational IPM programs. The only consideration of these models is in the influence they have had on current IPM programs.

The concepts on which proven IPM programs in Texas were built are relatively simple. There is a need, and in turn a limitation of this work, to consider in more detail the relationship of insects among crops, effect of irrigation and fertilizer, and to increase the effort to develop improved crop rotation systems. This does not imply that research in these areas is not being conducted in Texas, but rather, that some real opportunities exist in this area for IPM programs. This may be the next addition to proven IPM projects that will further improve efficiency.

MAJOR PROGRAMS

The major cotton insect pests in Texas are thrips (*Thrips tabaci*, and *Frankliniella spp.*), fleahopper (*Pseudatomoscelis seriatur* Reuter), boll-weevil (*Anthonomus grandis* Boheman), bollworm (*Heliothis zea* Boddie), and tobacco budworm (*Heliothis virescens*). Cotton IPM programs are basically designed to control these pests. Thrip and fleahopper cause economic damage only on very young and immature cotton and are relatively easy to control with insecticide application rates sufficiently low to not disturb the population of beneficials. Therefore, the boll weevil and budworm-bollworm complex represent the major economic pests relative to cotton production in Texas and are the focus of IPM programs.

In several areas, conventional or typical cotton production methods include an IPM program that has evolved over many years. Since these would be most difficult to identify and the primary interest is in relatively new IPM programs and how they compare to "conventional" production methods, only the newer IPM programs will be considered in this report.

Given the damaging insects and production regions in Texas, the basic components of IPM programs include (1) scouting or regular insect field counts, (2) reproductive-diapause boll weevil control, (3) seed variety selection, (4) defined cultural practices and (5) consideration of quantity and timing for applying production inputs such as water and fertilizer. Any particular IPM program may include one or more of these components. These are, of course, not unique to or developed solely by scientists in Texas. A contribution by Texas to IPM programs is the particular configurations and program delivery systems developed for the alternative production regions.

Nine basic IPM programs operational in Texas can be identified. For convenience, these are referred to as: (1) High Plains Program, (2) Glasscock County Program, (3) South Texas Program (4) Pecos Program (5) East Texas Program, and Extension Cotton Insect Management Program in four distinct cotton production regions of Texas (Rio Grande Valley, Blacklands, Trans-Pecos and Frio County).

Beyond the public-supported pest management programs in Texas there is considerable activity in pest management consulting in the private sector. There are approximately 30 entomologists that are members of the Texas Association of Consulting Entomologists (Frisbie, 1974 a). These individuals provide the producer with integrated pest management alternatives. In addition, there are 15 to 20 insect scouts that are not in the Association but that are private consultants to producers relative to insect populations and appropriate control (Frisbie, 1974 a). There are 300,000 to 400,000 acres of crops that are scouted in Texas annually by private consultants.

I. HIGH PLAINS PROGRAM

This is an area wide reproductive-diapause boll weevil control program. It began in 1964 and was designed to prevent the westward spread of the boll weevil into the more than 2 million acres of High Plains cotton, and possibily into New Mexico (Rummel, et.al.). This program represents the largest coordinated effort among states, federal agencies and producers ever undertaken to combat a cotton pest. Much of the material herein is based on an evaluation of the program by Rummel, et.al.

The Southern High Plains of Texas is the largest cotton producing area in the United States and has experienced few major cotton pest problems. However, the westward movement of the boll weevil threatens this area. Bottrell, et.al., documented the boll weevil onto the fringes of the Texas High Plains (1970). During 1963, there was substantial weevil damage in the Rolling Plains and on eastern margins of the High Plains (Rummel, et.al).

PROGRAM CHARACTERISTICS

To prevent or slow the advance of the boll weevil, diapause control was used. The technique used in 1964 was based on work by Brazzel indicating that insecticide applications before and during harvest season would significantly reduce overwintering boll weevil population (Brazzel, 1959; 1961).

In 1965, the program was expanded to include Knipling's hypothesis that a program designed to destroy the last reproductive generation of weevils would be more effective than aiming only at diapause weevils before they leave cotton (Rummel, et.al.). This concept was supported by Texas Agricultural Experiment Station research (Sterling and Adkisson, 1970).

In 1968, the program was again revised for a reduced budget. Since 1968, insecticide application is made only after a certain infestation level is reached. Inspection levels are determined by field survey and based on damaged fruit counts in August and September and adult weevil counts thereafter (specifics are available in Adkisson , et.al.).

USERS AND LOCATION

This is an area wide boll weevil suppression program. It is located in the Southern High Plains of Texas. The "Caprock", an escarpment which defines the eastern and southeastern limits of the High Plains, forms a distinct boundary between the High and Rolling Plains. The Rolling Plains abounds in habitat favorable for boll weevil overwintering. The juncture of the High and Rolling Plains serves as an excellent area in which to apply controls to limit boll weevil spread.

Insecticide applications to control the spread of the boll weevil were made near the Caprock in Rolling Plains cotton fields and where weevil infestations were identified on the High Plains. Therefore, primary users would be those producers on whose fields insecticide applications were made. They received weevil control at no direct cost.

However, the instigator of the program was Plains Cotton Growers, Inc. and would be identified as an organizational user. The Plains Cotton Growers, Inc. represent High Plains cotton producers. This, therefore, makes the cotton producers of the High Plains a program user. This involved 2 million acres of cotton and hundreds of producers with the vast majority farming more than 50 acres of cotton.

Acres treated normally were fields of less than 50 acres. Table D-1 indicates base acreage treated from 1964 to 1972. Some of these acres were treated more than once.

Table D-1. Cotton acreage treated under the Texas High Plains reproductive-diapause boll weevil control program[a]

Year	Acreage Treated	
	Base	Accumulated[b]
	1,000	1,000
1964	295	1,137
1965	250	1,512
1966	190	1,020
1967	118	501
1968	174	617
1969	217	769
1970	360	1,170
1971	133	380
1972	186	514

[a] Source (Rummel, et.al.)

[b] Some acres were treated several times in the control effort.

ASSESSMENT

Biological effectiveness

Biological effectiveness can be discussed in terms of overwintering weevils and yield implications. Yield implications are on an estimated annual basis due to the nature of the program while weevil number implications are available by year.

Weevil population: Estimates of the number of adult weevils per acre are made at weekly intervals throughout the growing season until a plant killing freeze (Rummel, et.al.). Table D-2 indicates estimated percent reduction in potential overwintering weevil population. In 1964, reduction in potential boll weevil population was about 82 percent. Records reveal that the overwintering weevil population in 1965 was over 9-fold less than the previous winter. By September 1965, there was some 40,000 less acres infested with weevils than at a comparable time in 1964.

In 1965 and 1966, the program was considered as highly effective (Rummel, et.al.). By 1967, weevil infestation had been nearly eliminated on the High Plains and reduced to such a low level in bordering area of the Rolling Plains that damaging infestations did not develop during the growing season. Infested acres had been reduced from 295,000 to 118,000 (Table D-1).

Since 1967, the program has been changed from previous years to a more limited basis with less applications on infested acres. The result has been a decrease in effectiveness of the program. Infestations in 1968 and 1969 were considerably further west with overwintering weevils

Table D-2. Estimated percent reduction in potential overwintering weevil population due to the High Plains reproductive-diapause program, 1964-1973[a]

Year	Percent reduction
1964	82
1965	99
1966	97
1967	86
1968	52
1969	43
1970	0
1971	69
1972	80
1973	0

[a] Source (Rummel, et.al.).

identified near the New Mexico border (Bottrell, et.al., 1972). These areas were intensively treated in 1970 and infestations have not reappeared (Rummel, et.al.).

Table D-3 presents overwintering boll weevil populations in overwintering habitat in suppression areas and adjoining untreated fields (Rummel, et.al.). At present, weevil distribution is similar to that at the initiation of the program in 1964, but infestation is much higher in

Table D-3. Overwintering boll weevil populations in overwintering habitat[a]

Date	Estimated number of overwintering weevils per acre	
	Treated	Untreated
Feb. 1967	21	806
April 1968	8	484
Jan. 1969	2,299	11,274
Jan. 1970	1,656	2,033
Jan. 1971	605	954
Feb. 1972	89	4,033
Jan. 1973	323	2,130
Feb. 1974	65	387

[a] Source (Rummel, et.al.).

the High Plains. There is presently no evidence of the establishment of the population west of the suppression zone boundaries (Rummel, et.al.).

It should be noted that a very high mortality rate of some 99 percent is experienced by boll weevils in the High Plains (Sterling). However, there is evidence that a weevil population in the High Plains is capable of adequate rates of increase to produce large numbers of migratory weevils during late season (Sterling and Adkisson, 1970). "There is little question that had the suppression program not been initiated, weevils would be established in many local areas of the High Plains and possibly in New Mexico where suitable overwintering habitat exists" (Rummel, et.al.).

Yield implications: The effect of the High Plains reproductive-diapause program on yield is that damages have been averted on the High and Rolling Plains. This is most difficult to quantify. However, an estimate of the expected annual yield effect was made in a recent study using several cotton production experts (Lacewell, et.al). Two estimates were made. The lower estimate of yield decline due to withdrawal of the program is emphasized in this report. In the High Plains, at least a 10 percent yield decline would be expected on 350,000 acres and 5 percent on 1,100,000. In the Rolling Plains, the yield decline that would be expected is 10 percent on 123,000 acres. Using average yields based on 1969, 1970 and 1971, 57,000 bales in the High Plains and 19,000 bales in the Rolling Plains (76,000 bales total) would be attributable annually to the High Plains reproductive-diapause boll weevil program; i.e., annual cotton output would have been expected to be at least 76,000 bales less without the program.

Cost and returns

This boll weevil suppression program was initiated by Plains Cotton Growers Inc., Texas A&M University, U.S. Department of Agriculture and Texas Tech University. The program operation costs are shared equally by cotton producers and the U.S. Department of Agriculture. Operation costs by item are presented annually. Overhead costs are estimated on an annual basis as well as implications of the program on producer costs of production.

Implementation: Included in implementation is only the program cost and not research leading to development of the program. The program began in 1964. Estimated implementation costs, in terms of scientific man years (SMY's) with a professional SMY cost inputed at $40,000 were as follows:

Unit	SMY	Cost
Texas Agricultural Experiment Station	.3	12,000
Texas Agricultural Extension Service	.6	24,000
USDA, ARS	.25	10,000
USDA, APHIS	Not available	

The SMY's for the Texas Agricultural Experiment Station, Texas Agricultural Extension Service and USDA-ARS were provided by Adkisson. Within the time frame of this study and number of years since implementation, data were not obtained for the APHIS division of the U.S. Department of Agriculture. The authors estimate this committment would at least equal that of the Texas Agricultural Extension Service which conservatively establishes an implementation cost of $70,000. An upper estimate of implementation costs of this program could have easily exceeded $100,000.

Annual overhead: Annual overhead, as implementation costs, are estimated in terms of SMY's and with $40,000 assigned per SMY. These costs, estimated by year are presented in Table D-4.

Table D-4. Estimated annual overhead costs associated with the High Plains reproductive-diapause boll weevil control program

Year	TAES[a]		TAEX[b]		Texas Tech[c]		U.S.D.A.[d]	Total Overhead
	SMY	Cost	SMY	Cost	SMY	Cost	Cost	Cost
1965	.5	20,000	.6	24,000	.5	20,000	87,339	151,339
1966	.5	20,000	.6	24,000	.5	20,000	51,723	115,723
1967	2.25	90,000	.6	24,000	.5	20,000	29,542	163,542
1968	1.75	70,000	.6	24,000	.5	20,000	34,482	148,482
1969	.75	30,000	.6	24,000	0	0	39,419	93,419
1970	.75	30,000	.6	24,000	0	0	61,743	115,743
1971	.75	30,000	.6	24,000	0	0	25,928	79,928
1972	.5	20,000	.6	24,000	0	0	32,520	76,520
1973	.5	20,000	.6	24.000	0	0	41,313	85,313

[a] Texas Agricultural Experiment Station (Adkisson).

[b] Texas Agricultural Extension Service (Adkisson).

[c] Texas Tech University (Adkisson).

[d] These data were being developed but were not provided in time to be included in this report. Therefore, an estimate of 10 percent of the U.S. Department of Agriculture share of annual operations cost was used. This value was indicated as not unreasonable by USDA personnel.

Estimated overhead costs of this program range from $163,542 in 1967 down to $76,520 in 1972. There is an indicated downward trend with the average annual overhead costs of the program for 1971-73 being $80,587.

Operation: Operating costs of this IPM program are equally shared by the High Plains Cotton Growers, Inc. and USDA, APHIS. These costs are presented in Table D-5.

Table D-5. Operation costs of the Texas High Plains reproductive-diapause boll weevil control program, 1964-1973.[a]

Year	Personnel cost	Insecticide cost	Application cost	Other[b]	Total[c]
1964	[d]	[d]	[d]	[d]	1,728,777
1965	[d]	[d]	[d]	[d]	1,746,779
1966	[d]	[d]	[d]	[d]	1,034,461
1967	[d]	[d]	[d]	[d]	590,839
1968	[d]	[d]	[d]	[d]	689,367
1969	[d]	[d]	[d]	[d]	788,373
1970	132,100	839,406	252,668	10,680	1,234,855
1971	131,130	257,866	94,072	35,500	518,568
1972	160,546	342,190	99,849	47,812	650,400
1973	172,180	449,738	136,195	68,142	826,255

[a] Source (U.S. Department of Agriculture, 1974 b).

[b] Other costs include per diem, motor pool, and miscellaneous expenses.

[c] These costs are equally shared by High Plains cotton producers and the U.S. Department of Agriculture.

[d] Itemized expenditures not provided for 1964-1969.

Annual operating costs of the High Plains reproductive-diapause boll weevil control program range from a low of $518,568 in 1971 to a high of $1,746,779 in 1965. There was a decline in program operating costs about 1970. With selective field control and a reduction in intensity of program, pressure on the boll weevil is reduced and a subsequent increase in population can be expected. This increase in population occurred in 1970 and can be expected to occur periodically.

The summation of program overhead and operating costs indicates total program costs. Total program costs for the last four years are as follows: 1970-$1.35 million; 1971-$0.6 million; 1972-$0.73 million, and 1973-$0.91 million. Over these four years, this gives an average annual program cost of $896,896 or about $0.9 million.

Producer: A major effect of the boll weevil suppression program on producers relates to his costs of production. As with yield, the effect can be estimated only on an average or expected basis. Also, a lower estimate of producer response due to withdrawal of the program is used (Lacewell, et.al.).

It is expected that without the program, producers would incur a yield decline and in addition apply much more insecticide in order to control the boll weevil. To evaluate this relative to producer costs, 1972 cotton enterprise budgets were used (Texas Agricultural Extension Service, 1974).

On the High Plains, in addition to the current two applications on 84,000 acres, without the program five applications would be applied on 350,000 acres and 1.5 applications on 1,100,000 acres. Similarly on the Rolling Plains, insecticide use above the current two applications on 260,000 acres, seven more applications would be applied to 123,000 acres (Lacewell, et.al.). These changes are expressed in dollar terms in Table D-6.

Table D-6. A comparison of expected cotton production costs with and without the High Plains reproductive-diapause program, 1972 basis[a]

Item	Unit	With	Without	Savings
High Plains				
Per acre	dollar	56.92	62.30	5.38
Per lb/lint	dollar	0.18	0.21	0.03
Aggregate	million dollar	119.60	131.00	11.40
Rolling Plains				
Per acre	dollar	33.29	35.92	2.63
Per lb/lint	dollar	0.17	0.186	0.016
Aggregate	million dollar	34.60	35.90	1.30
Total	million dollar	154.6	167.3	12.70

[a] Source (Lacewell, et.al.).

These data imply a $12.7 million dollar reduction in production costs due to the boll weevil suppression program in addition to a 76,000 bale increase in cotton output. This indicates that net returns to area cotton producers are increased $12.7 million plus the returns from 76,000 bales of cotton

This, of course, is only a presentation of fairly aggregate data across the region. The effect varies widely within the region. For example, producers in the Rolling Plains portion of the suppression zone reported that the program had reduced their in-season boll weevil control costs by as much as 60 percent (Pate, et.al.).

Environmental implications

Since this is a program designed to prevent or delay the westward spread of the boll weevil, a year by year evaluation is not appropriate. Rather, the expected annual effect is important. However, it is possible to identify program insecticide use annually (Table D-7). The principal insecticide used in the program has been malathion. Averaging over 1964 to 1972, 921,000 pounds of malathion and 7,000 pounds of azinphosmethyl have been applied annually.

Through the area wide boll weevil suppression program, however, some producers in the Rolling Plains and most producers in the High Plains have not been placed in a position of individually trying to control the boll weevil. With all producers acting independently to control a westwardly spreading boll weevil, insecticide applications would be expected to

Table D-7. Quantity and insecticide used for the Texas High Plains reproductive-diapause boll weevil program, 1964-1973 [a]

Year	Insecticide Malathion	 Azinphosmethyl	 Total
	---------- 1,000 pounds	----------	----------
1964	1,199	0	1,199
1965	1,834	0	1,834
1966	1,129	0	1,129
1967	513	7	520
1968	674	5	679
1969	631	44	675
1970	1,290	11	1,301
1971	440	0	440
1972	581	0	581
1973	747	0	747

[a] Source (Rummel, et.al.).

increase dramatically as discussed in the producer section on costs and returns (Lacewell, et.al.).

By expanding expected per acre increases of insecticide use over applicable acreages, quantity of insecticide that would be used in the absence of the program can be estimated (Table D-8).

Table D-8. A comparison of expected insecticide use with and without the High Plains reproductive-diapause boll weevil control program[a]

Insecticide	With[b]	Without	Difference
	1,000 pounds		
Malathion	921	0	-921
Toxapnene	395	5,367	4,972
Methyl parathion	427	4,629	4,202
Azinphosmethyl	7	0	-7
Bidrin	52	52	0
Total	1,802	10,048	8,246

[a] Source (Lacewell, et.al.).

[b] Includes insecticides used in the diapause program.

Data included in Table D-8 suggest that the High Plains reproductive-diapause boll weevil control program (using conservative estimates) is reducing the quantity of insecticides that would be introduced annually into the environment by 8,246,000 pounds (1,802,000 currently compared to 10,048,000 without the program).

Further implications are that by maintaining the High Plains as an area of very little to no insecticide use, beneficials are preserved for other area crops and danger to humans is reduced.

Regarding effect of the program, Huddleston found that late season applications of insecticide for weevil suppression did not cause a reduction of predacious insects the following year (Huddleston, et.al.). "In addition, no adverse effects on wildlife, domestic animals or humans have been detected during the 10-year program" (Pate, et.al.).

PROGRAM FEASIBILITY AND EXPANSION

This program has demonstrated, to a reasonable degree, that it has contributed to (1) increasing output of cotton, (2) reduced producer costs, (3) reduced pesticides that would be introduced into the environment and (4) has had no adverse environmental effects. Annual costs of the program is about $400,000 to High Plains cotton producers and $500,000 to the U.S. Department of Agriculture ($400,000 of which contributes to program operation), Texas A&M University and Texas Tech University. Annual returns are estimated to be at least $12 million in production cost reduction, over 76,000 bales of cotton and at least 8 million pounds less insecticide used.

An area wide diapause control program for boll weevils is a viable and productive program. The returns to producers and society far outweigh costs. Therefore, it is evident this program in this area should be continued. The form of continuation is of serious concern. Incentives to the producer (which are adequate if recognized) are sufficient that this group could continue the program. However, the nature of individuals throughout an area may require continued support from federal sources to assure coordination and program continuation.

An area wide diapause boll weevil control program can and has been expanded to other areas. An example is Glasscock County in Texas (discussed later in this report). In addition, diapause control is an integral part of any effective IPM program that involves boll weevil control.

An area wide diapause boll weevil control program designed to suppress movement requires a natural barrier or isolation, such as the Caprock at the edge of the Texas High Plains. Indications are that relatively small and isolated cotton production areas already infested with boll weevils provide a situation where success can be expected in controlling boll weevil through an area wide diapause program.

II. GLASSCOCK COUNTY PROGRAM

The Glasscock County Program is a fall diapause boll weevil program. It differs from the High Plains program in that the area was already infested, hence, the program was designed to control boll weevil over the infested area. In 1967, adult boll weevil counts were up to 28,000 per acre in the area (Neeb and Cole). Damages from the boll weevil were estimated to be 1/3 to 1/2 bale per acre (Neeb and Cole). In response, a fall diapause control program was initiated for the purpose of obtaining area wide boll weevil control.

PROGRAM CHARACTERISTICS

To carry out this IPM program, the St. Lawrence Cotton Growers Association was formed in 1968 (Neeb and Cole). During 1968, the program was totally producer financed. Since 1968, program costs have been equally shared by producers and the Texas Department of Agriculture. Also, the Texas Agricultural Experiment Station and Texas Agricultural Extension Service cooperated with the St. Lawrence Cotton Growers Association in the program.

The purpose of this program was to reduce boll weevils sufficiently so that in-season control would not be needed (Neeb and Cole). By alleviating the need for in-season control, beneficials are preserved and, hence, major problems with the bollworm averted.

The program began in the fall of 1968. For 1968, 1969 and 1970, all acres were treated at least once with some acres treated three times about 10 days apart (Thomas). Spraying began soon after diapause incidence began to increase noticeably in the adult boll weevil population. In 1970, only fields found to be infested were treated. Guthion was used in the diapause program for boll weevil control in 1968 with ULV malathion used in 1969 and 1970 (Neeb and Cole).

The program was initiated through planning meetings with producers given technical information by Texas Agricultural Experiment Station and Texas Agricultural Extension Service entomologists (Neeb and Cole). Success in implementing this and any similar program lies with strong local leadership of producers and organizational support of cooperating agencies. These were very evident in initiating this program (Thomas).

USERS AND LOCATION

The principal user of this IPM program is the St. Lawrence Cotton Growers Association. This includes cotton producers in the St. Lawrence area. Initially the program was centered on 15,000 acres and had 100 percent producer participation (Neeb and Cole). The majority of acreage in the program is located in Glasscock County with some located in Reagan and Upton Counties, and a small amount in Midland County.

In 1971, the program was extended to 1,200 acres not included previously (Thomas). Therefore, the program area has been 16,200 acres since 1971. In the area where the added 1,200 acres of cotton were included in the program in 1971 (northeast part of Glasscock County), there was less than 100 percent producer participation up to 1973 which reduced effectiveness of the IPM program in the area (Neeb and Cole). In

1973, there was 100 percent participation in the program.

Acres treated in the Glasscock Counyy diapause program are presented in Table D-9. Acres treated declined from 46,813 in 1968 to 3,500 in 1972 and increased back to 10,700 in 1973. Increased acreage in 1973 was due primarily to lack of a reproductive weevil control program on isolated cotton acreage in the latter part of August.

Table D-9. Cotton acreage treated under the Glasscock County diapause boll weevil control program[a]

	Program diapause Applications	
Year	Grower applied with defoliant	Treated in county program[b]
1968	8,500	46,813
1969	8,500	46,775
1970	8,500	54,500
1971	7,500	2,400
1972	0	3,500
1973	4,000	10,700

[a] Source (Thomas).

[b] Multiple treatments of cotton acres and planting in skip row patterns explains the excess above 15,000

The best indication of distribution of producers by size operations (distribution of users by acres of cotton is not available) is provided by the 1969 Census of Agriculture (U.S. Department of Commerce) For Glasscock County, in 1969, there were 12 producers that harvested less than 50 acres of cropland, 41 harvested 50 to 200 acres of cropland and 52 harvested more than 200 acres of cropland. In 1969, 93 farmers harvested 11,651 bales of cotton from 16,325 acres. This was from a county total of 31,552 acres of all crops harvested by 105 farmers.

ASSESSMENT

Biological effectiveness

Biological effectiveness can be measured in weevil population. In 1967, adult boll weevil counts were running as high as 28,000 per acre (Neeb and Cole). The program began in 1968 and in 1972 in the St Lawrence area no weevils were detected and no chemical applications were made in the diapause control areas. Considering the total region (including parts of Upton, Reagan and Midland Counties), Table D-9 shows a reduction in acres treated which is a measure of reduced weevil infestation.

An attempt to evaluate yield changes due to the diapause program is difficult since the records of individual producers are not readily available and acreage of cotton doubled from 1968 to 1972 (Texas Crop Reporting Service). Not only did cotton acres change significantly, but the proportion of irrigated and non-irrigated acres shifted. Therefore, attempts to use county statistics of yield are of little value.

Although a yield increase cannot readily be documented due to the diapause program, cotton specialists are convinced that the massive reduction of boll weevil population per acre reduced boll weevil damages substantially and caused some yield increase. Based on this, the following analysis is comfortably based on an assumption of no yield change.

Costs and returns

This IPM program was initiated by a local producer group (St. Lawrence Cotton Growers Association) who funded all operating costs for the first year, 1968 (Neeb and Cole). However, cooperation was provided by the Texas Agricultural Extension Service and this support has continued (Thomas). Since 1969, program operations costs have been equally shared by producers and the Texas Department of Agriculture (Neeb and Cole).

Implementation: Efforts to implement the Glasscock diapause boll weevil program began in 1967 and continued into 1968. Included as implementation costs is time expended by the Texas Agricultural Extension Service, Texas Agricultural Experiment Station and the cotton producers association up to the first spraying. Estimated time required for implementation was: (1) Texas Agricultural Extension Service -- 80 scientific man days or .35 SMY (scientific man year), (2) Texas Agricultural Experiment Station -- 20 scientific man days or about .1 SMY, and (3) St. Lawrence Growers Association -- 60 man days (Neeb and Werst). Valuing a SMY at $40,000, implementation costs not incurred by producers is an estimated $14,000 for the Texas Agricultural Extension Service and $4,000 for the Texas Agricultural Experiment Station or a total of $18,000.

Operation: Operation costs of the diapause program include insecticide applications as well as support provided by Texas Agricultural Extension Service entomologists and Texas Department of Agriculture. Table D-10 indicates man days used for the operation of this IPM program.

The time allocation of Table D-10 and direct program costs for 1968 through 1973 are summarized into total program costs in Table D-11. Texas Agricultural Extension Service time is included in program implementation. In connection with this program, the St. Lawrence Cotton Growers Association employs a bookkeeper for about 30 days to bill farmers for spraying and to maintain records. The Texas Department of Agriculture employs scouts that begin work in August. The scouts monitor fields and calibration of actual spray operations.

The total cost of the program increased through 1970 ($99,110) and has declined substantially since then. Costs were minimal in 1972 at an estimated $10,961. With selective field control, pressure on the boll weevil is reduced and a subsequent increase in population can be expected. This happened in 1973 when infestation was discovered in more acres than in the Texas High Plains diapause program (Rummel, et.al.).

In 1971, 1972 and 1973, all producers in the St. Lawrence Growers Association contributed 10 cents per acre of cotton to be applied to diapause control costs. This amounted to about one-fourth of the diapause spraying program costs, hence, for those producers with fields treated in the diapause program, their costs were reduced to about one-fourth of the total chemical and application costs (The Texas Department

Table D-10. **Man days used for operation of the Glasscock County diapause boll** weevil program[a]

Year	TAEX[b]	TDA[c]	Bookkeeper[d]	Producer[e] Association
1968	f	0	30	f
1969	60	100	30	40
1970	50	100	30	40
1971	30	50	30	30
1972	20	30	30	30
1973	20	5	30	30

[a] Source (Neeb and Werst).

[b] Texas Agricultural Extension Service with approximately 250 days a scientific man year.

[c] Texas Department of Agriculture scouts with cost about $150 per 5 days including salary and mileage.

[d] Bookkeeper hired by the producers at $15 per day to bill farmers for spraying and maintain program records.

[e] Time producers used to solicit cooperators.

[f] Included in implementation time and costs.

Table D-11. Diapause chemical and application costs and estimated overhead for the Glassock County diapause boll weevil control program

	Direct Cost[a]			Overhead[b]				
				St. Lawrence[c]	TAEX[e]			
Year	Producer	TDA[d]	Total	Growers Assn.	SMY	Dollars	TDA[f]	Total
	dollars	dollars	dollars	dollars	Man years	dollars	dollars	dollars
1968	86,636	0	86,636	450	g	g	0	87,086
1969	35,004	35,004	70,008	450	.25	10,000	6,800	87,258
1970	41,600	41,600	83,200	450	.20	8,000	7,460	99,110
1971	5,925	5,925	11,850	450	.12	4,800	2,242	19,342
1972	3,010	3,010	6,020	450	.08	3,200	1,291	10,961
1973	11,296	11,296	22,592	450	.08	3,200	1,295	27,537

[a] Source (Thomas).

[b] Source (Neeb and Werst).

[c] Does not include a cost for producers time, i.e., 'days' shown in Table D-11. Based on a bookkeeper for 30 days at $15 per day.

[d] Texas Department of Agriculture.

[e] Texas Agricultural Extension Service. Cost is based on $40,000 per scientific man year.

[f] Cost of Texas Department of Agriculture scouts and a charge of 10 percent of TDA expenditures on this program for overhead. Scout costs are $150 per 5 days.

[g] Included in implementation time and costs.

of Agriculture paid for one-half of the control costs). This is a good example of all producers cooperating in monetary support of a program. However, due to regional implications of the program, an even more equitable cost sharing arrangement among producers would be an equal sharing among all beneficiaries (producers).

Producer: The IPM program's impact can be identified in terms of insect control costs incurred by the farmer on a typical acre of cotton. Table D-12 shows in-season and diapause application per acre costs to the producer.

The effect of the diapause boll weevil control program is positive in reducing insect control costs. Even with an assumption of no yield difference since the program was initiated, the reduced costs represent increased producer profit. A $10.00 per acre reduction in costs (increase in net returns if yields are unchanged) over 15,000 acres amounts to $150,000. Total insect control costs (including everything but supporting agencies overhead) declined from about $180,000 in 1967 to $6,660 in 1972 and $22,792 in 1973 (Thomas). This can be measured as a positive effect on insect control and cotton production in the region.

Environmental implications

A principal measure of environmental implications is quantity of insecticide applied. An indirect measure of insecticide applied is costs of insect control. In Glasscock County, with the diapause boll weevil control program, insect control costs declined from $12.00 per

Table D-12. Average per acre insect control costs of cotton production in Glasscock County and effect of a diapause boll weevil control program[a]

Year	In-season cost	Producer supported diapause control cost	Total producer	Total[b] County
	----------dollars----------			
1967	12.00	0	12.00	12.00
1968	12.00	2.89	14.89	17.78
1969	4.00	2.43	6.43	8.86
1970	.20	2.84	3.04	5.88
1971	.01	0.40	0.41	0.81
1972	.04	0.02	0.06	0.08
1973	.01	0.75	0.76	1.51

[a] Source (Thomas).

[b] Does not include overhead of the Texas Department of Agriculture or Texas Agricultural Extension Service.

acre to less than $2.00. On cotton acres initially in the program, excluding acres added in 1971, cost of in-season insect control declined to $0.08 per acre in 1972 and there was no diapause applications (Neeb and Cole). This is a reduction to essentially zero of quantity of insecticides used. Even including the new 1971 acres in the program, the analysis indicates a reduction of insecticides introduced into the environment of several fold.

Through the diapause program, in-season spraying in the control area has been essentially eliminated. By stopping the in-season control for boll weevil, the diapause program is responsible for the preservation of beneficials (Neeb and Cole). If the beneficials were destroyed, it is likely bollworm populations would increase to damaging levels and bring about a new and vigorous surge of insecticide applications. The evidence is that this prospect has been very substantially reduced or eliminated.

PROGRAM FEASIBILITY AND EXPANSION

For the St. Lawrence area, the program has: (1) 100 percent producer participation, (2) substantially reduced boll weevil population thereby eliminating the need for in-season applications, (3) reduced quantity of insecticides introduced into the environment, (4) reduced insect control costs and (5) in all probability has been associated with an increase in cotton yield. Therefore, this program has very well demonstrated itself as viable and most successful.

There are opportunities to expand this IPM program and, in fact, it was expanded in 1971. Tom Green, Concho and Runnels counties have begun to initiate programs similar to the Glasscock County program (Neeb and Cole).

One of the keys to success in Glasscock County was the enthusiasm and support of the area extension entomologist and total committment of the producers in the area. A deficiency in either of these will be a serious impediment to expansion of the Glasscock County diapause program. In addition, it must be recognized that the requirements for maximum boll weevil control will differ in certain geographical areas, hence, the boll weevil will have to be dealt with on an area by area basis (Thomas).

III. SOUTH TEXAS PROGRAM

Cotton producers in the Rio Grande Valley of Texas use quantities of insecticides on a per acre basis that are among the highest in the nation. This is due to the many different undesirable insects and especially to increasing insect tolerances to insecticides. With insect (tobacco budworm) resistance to insecticides, a tendency exists to increase number of insecticide applications which further compounds the problem. Even with large amounts of insecticide use, the control of damaging insects has been unsatisfactory. Cotton yields have been declining while production costs, including insecticide costs, have been rising.

Farmers have been unable to control mid and late season tobacco budworm which are often aggravated by early season boll weevil and fleahopper control (Namken and Heilman). There are some cases of over 20 applications of insecticide with only limited effectiveness. Scientists of the U.S. Department of Agriculture, Texas Agricultural Experiment Station and Texas Agricultural Extension Service all located at Weslaco have developed an integrated pest management strategy effort to gain more effective control of insect infestations and maintain per acre cotton yields. The IPM program strategy switches production to a short season cotton variety, applies boll weevil diapause control and uses scouting reports as a basis for deciding on need and application of insecticide.

PROGRAM CHARACTERISTICS

Basic differences exist in methods of producing cotton on 38 to 40-inch row spacings in the conventional 160 to 180-day season (traditional production) as compared to narrow row spacing (double row 10 inches apart on 38 inch rows, for example) and a 120 to 140-day growing season (narrow row-short season production).

The discussion reported here applies to irrigated cotton production on medium textured soils in the Lower Rio Grande Valley and is based largely on research by Namken and Heilman. In addition, enterprise budgets as developed by the Texas Agricultural Extension Service for the area provided baseline data for operations. Much of the data for this report are taken from an evaluation done by the Texas Agricultural Experiment Station in cooperation with U.S. Department of Agriculture and Texas Agricultural Extension Service (Larson, et.al.).

General

Traditional production: Typical production practices relative to cotton in the area include three irrigations, pre-emergence herbicide treatment, defoliant preceeding harvest and fertilizer application of 60 pounds of N and 40 pounds of P per acre (Larson, et.al.).

Narrow row-short season: The major general production difference of narrow row-short season as compared to traditional production, is 10 more pounds of seed planted per acre (30 pounds compared to 20 pounds) and only one irrigation (Larson, et.al.). Of course, in any particular year the operations and inputs will vary, however, the relationship between the two production systems is expected to remain relatively similar.

Of major importance in the narrow-row, short-season production system is early harvesting of cotton, before August. This means cotton is harvested before the normally large rains that begin in August, hence, the crop residue can be destroyed and boll weevil overwintering habitat removed.

Insect control

The most striking difference between traditional cotton production and the narrow-row, short-season cotton involves opportunities for improved pest management strategies. Table D-13 indicates expected insecticide use for each type of cotton production.

Table D-13. Expected pounds of insecticide use for two cotton production practices in the Texas Rio Grande Valley[a]

Chemical	Unit	Production System		
		Traditional	Short-season	Difference
Bidrin	lbs/acre	.03	.03	0.0
Methyl parathion	lbs/acre	11.25	7.50	-3.75
Fundal	lbs/acre	0.85	0.51	-0.34
Total insecticide	lbs/acre	12.13	8.04	-4.09

[a] Source (Larson, et.al.).

Traditional: Fleahopper control is normally conducted on only about one-third of the cotton acres. For boll weevil, application of insecticides is delayed as long as is economically justified. This is done to maximize biological control of the bollworm and budworm.

The boll weevils typically begin laying eggs about April 15. This means that around May 10, the first eggs will be hatching (first generation). Insecticide applications begin about mid May to control this first generation of boll weevils and usually involve methyl parathion applied at 1.5 pounds per acre. A second treatment of methyl parathion follows in a few days also for control of boll weevil.

The use of methyl parathion for boll weevil control reduces the beneficials and the bollworm and budworm emerge as economic pests. Therefore, throughout the remainder of the growing season (into August), 4 or 5 treatments of a mixture of fundal and methyl parathion (at 1 and 0.125 pounds per acre, respectively) are applied for control of boll weevil, bollworm and budworm. This will, of course, vary considerably reaching as high as 15 to 20 insecticide applications in a "bad" insect year (Larson, et.al.).

Narrow row-short season: Narrow-row, short-season cotton production is based on high density plant population, short season cotton variety and accelerated fruiting. The concept of pest control, not yet totally proven but indicating most promising results, varies significantly from traditional practices.

Overwintering boll weevils begin emerging about March 1 concurrent with development of pinhead squares. Around April 15 the squares are about one-third grown and boll weevils begin laying eggs. A pest management strategy being developed and tested for the narrow row-short season cotton suggests treatment for boll weevil should begin before it lays eggs. Following the treatment of boll weevil with methyl parathion just prior to laying eggs, a second boll weevil treatment is applied five days later. This is designed to reduce the later population and delay egg lays to later in the season (Larson, et.al.).

Spraying as above is expected to delay the first generation by 10 days. The narrow-row, short-season cotton begins blooming in early May and blooms at double the rate of traditional cotton. The percent of bolls that set are about the same for both types of cotton, hence, narrow-row, early-season cotton has more bolls much earlier.

The two treatments for boll weevil in April results in the second generation of boll weevils not being a problem until July. Ineffective control of the boll weevils emerging from overwintering will result in the first generation being an economic problem about May 10 and continued boll weevil treatment required.

Even with successful control of the first generation, the bollworm will begin to be an economic problem around June 15. Therefore, two treatments for bollworm control could be expected with narrow-row, short-season cotton. There are, however, indications that early boll weevil control (April) results in better biological control of the bollworm via beneficials (Larson, et.al.)

USERS AND LOCATION

This IPM program was developed by scientist at Weslaco in the Rio Grande Valley. The program was designed for cotton production particularly in the Lower Rio Grande Valley. In 1973, approximately 10 to 15 percent of the farmers in Hidalgo, Cameron, and Willacy counties were growing short season cotton. Scientists involved in developing and testing the program have assisted many area farmers in an effort to promote the program.

This program has been developed with respect to the peculiar production characteristics of the Rio Grande Valley. The total acres, which represent a potential for coverage by the program, are given in Table D-14.

Table D-14. Total acres of cotton produced by county in the Texas Rio Grande Valley in 1973[a]

County	Acres
Hidalgo	93,000
Cameron	81,900
Willacy	9,300
Total	184,200

[a] Source (Texas Almanac).

ASSESSMENT

Research results were used to develop enterprise budgets with and without the program. An analysis based on average data for the early maturing and conventional cotton was performed and comparisons made (Larson, et.al.).

Biological effectiveness

A major contribution of the new strategy is maintaining average yields with lower production costs due to increased natural regulation of cotton pest.

The bloom rate of the short season cotton is more rapid and remains higher throughout peak bloom (Namken and Heilman). A good fall diapause program will control first generation weevils the following year. Thus, by the time second generation weevils begin appearing most of the early maturing cotton will be set (Namken and Heilman). Historically, bollworms do not become of economic importance until mid June. By avoiding early season boll weevil treatments, the bollworm can be biologically controlled until mid June (Namken and Heilman). Only 3 - 4 insecticide applications would be necessary to control budworm before defoliation began about the first of July.

Under this program, harvest would be completed by August when the rainfall usually increases in the region. This practice would minimize the cover for overwintering quarters of boll weevil. Traditional cotton varieties often have harvesting continuing into September.

Costs and returns

The IPM program developed for the Rio Grande producers is for a particular pest problem. With an evaluation available on this program, economic implications appropriately emphasize producers in the Rio Grande Valley. Research costs are not included and the effort to extend the program has been informal and not of an organized nature. Therefore, cost to extend the program at this stage are essentially zero. Viability of the program is evident in that 10 to 15 percent of the cotton acreage is in short-season cotton varieties and increasing annually.

The grower's production costs with the short-season cotton variety include $5.00 per acre for a cotton scout, costs of insecticides, and normal production inputs. Table D-15 gives the costs and returns to producers with and without the IPM program (Larson, et.al.).

Data in Table D-15 clearly indicate that producers would be in a favorable position under the IPM program. Returns are the same for both conditions due to sustained yields with early maturing cotton. However, production costs are reduced significantly due to the reduction in insecticide costs.

Estimated insecticide costs decrease by $10.14 under the IPM program. Annual insecticide costs for conventional cotton are approximately $28.91 per acre compared to $18.77 for short season cotton. This reduction in insecticide costs along with equivalent yields results in greater net returns per acre for the producer under the IPM program. Net returns for conventional production is estimated to be $37.27 while

Table D-15. A comparison of expected costs and returns for two cotton production systems in the Rio Grande Valley[a]

Costs and Returns	Production System Traditional	 Short season	Difference
Returns	303.60	303.60	0
Insecticide costs	28.91	18.77	-10.14
Scout	5.00	5.00	0
Other variable costs	152.15	146.46	-5.69
Total variable costs	131.06	165.23	-15.83
Fixed costs	85.27	82.60	-2.67
Total costs	266.33	247.83	-18.50
Net returns	37.27	55.77	18.50

[a] Source (Larson, et.al.).

under the IPM program net returns are estimated to be $55.77 or an increase of 18.50 per acre.

Environmental implications

A major change in expected operating inputs with the IPM program compared to the conventional control is the total amount of insecticides applied per acre. Table D-13 gives the amount of insecticides applied per acre with and without the IPM program.

The use of bidrin to control early season pest such as flea-hopper and thrips is unchanged. However, due to the early maturing cotton in the IPM program, fewer treatments are required for boll weevils, bollworms, and budworms. Methyl parathion is reduced from 11.25 to 7.50 pounds per acre, a decrease of 3.75 pounds per acre. Fundal is reduced by one-third from 0.85 pounds to 0.51 pounds per acre. Thus, total insecticide use could be reduced by an estimated 4.09 pounds per acre under the IPM program.

Much of the recent emphasis on environmental quality has been concerned with reducing the amount of insecticide being introduced into the environment. The Rio Grande Valley has a history of heavy applications every year. Extrapolating the per acre results to all irrigated cotton acres in the valley gives an estimated reduction of 753,378 pounds of insecticides that would not be used in the region by adoption of the program (2,234,346 compared to 1,480,968).

In addition to a reduction in total pounds of insecticide used, other environmental benefits are associated with the program. The Texas Rio Grande Valley is a region of diverse agriculture with cotton, grain sorghum, many vegetables and a citrus industry. At current rates of insecticide use for cotton production, the insect eco-system in citrus is disturbed. This represents a cost to citrus producers. Hence, by reducing pounds of insecticide used on cotton, some substantial benefits would be derived by citrus producers.

PROGRAM FEASIBILITY AND EXPANSION

Through research plots and with selected growers in the valley, results indicate the narrow-row, short-season cotton production system is preferable to traditional production practices. Implications of this study are that if this IPM program was extended to the 184,200 irrigated acres of cotton in the Rio Grande Valley, no output would be lost while net returns would increase over $2.7 million and quantity of insecticides introduced into the environment would be reduced by 753,000 pounds annually. The evaluation of the program suggests that it is a viable program and with implementation throughout the valley, it is expected that cotton pests could be successfully controlled without exclusive reliance on chemicals.

Indications are that an education and assistance program for producers is needed to increase the rate of adoption throughout the region. Federal funded projects for demonstrations in a wide area would be expected to increase producer confidence. Even greater results of this type IPM program are expected when all producers cooperate. Aspects of this program could, and are, being incorporated into the scout program for the region.

IV. PECOS PROGRAM

During the past several years in the Pecos area of Texas, insect control costs have been increasing while average yields have been decreasing. In 1968, the regional Texas A&M Research Station introduced an integrated pest management system that incorporated insect control into overall cotton production practices such as recommended irrigation and fertilizer levels. This is for an area with limited rainfall (semi-arid), hence, the producer has control over the timing and rate of irrigation water use.

Principal insect problems in the Pecos area are fleahopper, lygus, pink bollworm and bollworm-budworm complex. Traditional control of insects in cotton produced in the Pecos involved periodic insecticide application.

With the limited rainfall, the Pecos is an area where an integrated pest management program could be most effective because many factors of production can be controlled by the farmer. This section describes the program developed and indicates the potential benefits of such a program.

PROGRAM CHARACTERISTICS

This IPM program was designed to apply insecticides based on specified damage levels rather than by date or simply presence of insects (Pate, et.al.). Treatment only when damaging levels of insects were present along with sound crop management allowed beneficials to increase, thus help in the natural regulation of pests. The program consisted basically of six steps (Pate, et.al.):

(1) Weekly scouting until cotton began to square

(2) Twice a week scouting until crop termination

(3) Application of insecticide based on specified damage levels

(4) Emphasis on early maturing crop

(5) Optimum fertilization and irrigation with caution not to over fertilize or irrigate

(6) Diversified cropping to provide shelter and hosts for beneficials year round

The first three techniques are concerned with eliminating some of the large amounts of insecticides that were traditionally applied. Each of the three is based on scouting reports or counting the insects and then applying insecticides only when undesirable insect populations exceed specified damage levels. The last three practices were designed to complement the first three principally by regulation of beneficials. An early maturing crop eliminates the need for any insecticide treatment during September, thus allowing the number of beneficials to increase. During production over fertilization or irrigation were avoided so that excessive vegetative growth was not present in the late stages of production. Diversified cropping was practiced to provide shelter and hosts for beneficials year round. Thus, conservation of beneficials to aid in the natural regulation of cotton pests was an integral part of the new strategy.

USERS AND LOCATION

This IPM program was initiated by the Pecos Research Station in 1968. The purpose was to develop improved cotton production in the West Texas counties of Pecos and Reeves County. Since 1968, over 42,000 acres have annually been planted in cotton (Thomas).

The IPM program has been successful in reducing insecticide control costs while maintaining yields for six years, 1968-1973. However, not until 1970 did some of the area farmers implement similar programs (Pate, et.al.). These producers were able to cut insecticide control costs in half in most cases. The indication is that more farmers are adopting the program or some components thereof each year.

Currently, the principal user of the program is the Pecos Research Station with much of the adoption of the program restricted to farms in the immediate vicinity of the Station. There is evidence that components of the program are being adopted in a spinoff fashion based on results of early adopters. There is a need to implement adoption of the program throughout the region through the use of cotton production specialists that work closely with farmers making overall production recommendations.

ASSESSMENT

Each year a different insect situation was present on the Pecos Research Station. Prior to 1968 production, it was decided that fleahopper and lygus would not be chemically controlled if the cotton crop was setting at least 50 percent of initiated squares (Pate, et.al.).

Bollworm treatment would not be started as long as only 9-10 percent damage was present prior to boll set. After bolls were a half inch in size, the damage level was reduced to 5 percent. Pink bollworm control was initiated if 5 to 10 percent of bolls became infested. The observed pest population damage was different for each year (Pate, et.al.).

Biological effectiveness

Only in 1968 did the Pecos Research Station apply any insecticides. One treatment was needed for an outbreak of beet armyworms (Pate, et.al.). Bollworms, thrips, fleahoppers, and lygus infestations were low until September, but they still did not reach a level requiring treatment. Pink bollworm damage reached 5 percent, but this was below the population level established for treatment.

Insecticides were not applied on the cotton in 1969. Fleahoppers, thrips, and lygus were not a problem, but bollworm damage reached 10 percent in July (Pate, et.al.). Increased numbers of beneficials helped to prevent the population level from reaching the predetermined economic threshold. Pink bollworm infestation were also light in 1969.

In 1970, fleahopper, thrips, and lygus population were increased, but not high enough to justify treatment. Bollworm populations were moderate, but never exceeded 6 percent; this is not considered damaging enough to initiate treatment (Pate, et.al.).

Table D-16 shows the number of treatments and the insecticide costs per acre for the Pecos Research Station and the surrounding two

Table D-16. A comparison of number of insecticide applications and insect control cost at the Pecos Research and Extension Center and the surrounding counties: Reeves and Pecos Counties[a]

Item	Unit	1968	1969	1970	1971	1972	1973
Insecticide applications per acre							
Pecos Research and Extension Center	no.	1	0	0	0	0	0
Pecos County	no.	12	12	10	9	8	9
Reeves County	no.	10	10	10	9	7	9
Insecticide cost							
Pecos Research and Extension Center	$/acre	1.30	0.00	0.00	0.00	0.00	0.00
Pecos County	$/acre	33.00	33.00	27.50	24.75	22.00	36.00
Reeves County	$/acre	30.00	30.00	30.00	24.75	19.25	36.00

[a] **Source** (Pate, et.al.).

counties (Pecos and Reeves). Under the IPM program, only one application of insecticide was applied in six years, while 8 to 12 applications per year were applied to each acre in the surrounding counties. Under the IPM program the insect populations were continuously monitored and chemicals applied only if predetermined economic threshold levels were reached. Thus, the program was biologically successful as natural insect control was considered sufficient for protection of the cotton crop.

The lower number of applications of insecticide significantly reduced insect control cost. The research station incurred only $1.30 per acre insecticide costs for the six-year period 1968-1973, while the surrounding counties averaged about $29 per acre annually over the same period. However, the cotton scout was an added cost under the IPM program. Under this program, $5.00 or more per acre are required annually for a scout. The reduction in insecticide costs and the maintenance of yields, as shown in Tables D-16 and D-17, indicate the overall feasibility of this program.

Another measure of success of an IPM program relates to the effect on per acre yield. Table D-17 gives a comparison of annual yields for the six-year period on the Pecos Research Station with the IPM program and in Pecos and Reeves counties without the IPM program. The average yield for the research station is 777 pounds or approximately equal to the per acre yield of Reeves County (770 pounds). However, the average yield per acre under the IPM program is significanly greater than the yield without the program in Pecos county, 770 compared to 599 pounds per acre. Another important point emphasized by these data is that in some years yields would be larger using the traditional pest control tactics, 1973 for example. However, over the long run, the integrated pest management program appears to be most desirable in terms of yield and insect control.

Table D-17. A comparison of yield on the Pecos Research and Extension Center and in the surrounding counties of Pecos and Reeves County[a]

Item	Unit	1968	1969	1970	1971	1972	1973(Av)
Pecos Research and Extension Center	lbs/acre	752	984	625	800	875	625(777)
Pecos County	lbs/acre	730	536	511	539	496	750(599)
Reeves County	lbs/acre	869	751	659	818	770	750(770)

[a] Source (Pate, et.al.).

The data on insecticide costs and annual yield from the Pecos Research Station and the Pecos-Reeves County area indicate that the IPM program can be successfully used by area cotton producers. Production under the program reduced insecticide control costs dramatically while yields were maintained or increased. The presence of yields consistent with the surrounding counties provide an indication that the pest problem is managed as well under the IPM program as under a strategy of automatic application of chemical insecticides.

Costs and returns

Most of the costs for this program have been for research and demonstration. Also, since the Trans-Pecos program, to be discussed later in this report, can be considered as the effort to extend the Pecos strategy described herein to producers, this section emphasizes the potential of the strategy to producers.

Approximately 42,000 acres of cotton are planted in Reeves and Pecos Counties annually. It is estimated that up to one million dollars could have been saved if the IPM strategy had been expanded to the two counties (Pate, et.al.). Table D-18 shows the potential reduction in county insect control costs based on all acres of both counties participating in the program.

In Pecos County, it is estimated that a reduction of over $550,000 in insecticide cost could have been realized annually by using the IPM program. Over the six-year period an average of $290,000 annually (or 3.5 cents per pound of cotton lint) could have been saved under the program. Even more significant, in Reeves County, the data indicate that over one million dollars of insecticide expenditures (or 5 cents per pound of cotton lint) could have been avoided under this program. A six year average showed an annual saving of insect control costs of $884,000 would have been possible with area-wide adoption of the Pecos program from 1968-1973 (Pate, et.al.).

Table D-18. Expected reduction in insect control costs through the adoption of an integraged pest management program in Pecos and Reeves Counties, Texas; 1968-73 [a]

Unit	1968	1969	1970	1971	1972	1973
Cotton Acres						
Reeves	37,200	35,400	33,500	25,500	28,200	29,000
Pecos	17,340	14,200	10,000	6,400	7,000	4,388
Potential savings per pound						
Reeves(¢/lb.)	3.25	4.00	4.56	3.03	2.50	4.80
Pecos(¢/lb.)	4.35	6.16	5.39	4.59	4.44	4.80
Potential County reduction						
Reeves (dol.)	1,060,319	1,063,416	1,006,688	633,027	501,930	1,044,000
Pecos (dol.)	550,631	468,849	274,918	158,336	132,120	143,968

[a] Source (Pate, et.al.).

Environmental implications

The principal difference in production with and without the IPM program is the insecticide applications. Total pounds of insecticides vary from year to year. The annual number of applications will be used as a proxy for quantity of insecticide applied. The average number of annual applications on the Pecos Research Station and in Pecos and Reeves counties is shown in Table D-16.

Much of the recent emphasis on quality of the environment has been directed at decreasing the amount of chemical pesticides being introduced into the environment. Insecticide applications are reduced by 7 to 10 total applications in each year. A minimum of 7 applications were made (Pate, et.al.) without the program while only one application was made in six years under the program. Therefore, the program is obviously preferred over traditional practices since use of insecticides is reduced to essentially zero and yields are, at least, maintained. This is a program that uses improved production and cultural practices and relies heavily on natural or biological control of harmful insects.

PROGRAM FEASIBILITY AND EXPANSION

In the past few years, yields have been declining while production costs, including insect control costs, have been increasing. To 1973, this area had the highest production costs per pound of lint produced in the United States. The Pecos Research Station has demonstrated a feasible alternative for reducing the amount of insecticides used and reducing production costs while maintaining annual yields. This IPM program was developed in 1968 in an effort to develop an alternative production strategy for the Pecos area farmers.

As early as 1970, some of the farmers in the area of the research station were adopting similar programs. All of the early participants of the new program were not able to achieve the level of success of the Pecos Research Station. However, the producers were able to cut insect control costs in half with many actually avoiding any application of insecticides. Farmers of the area need some technical assistance when developing a new program. There is currently a need for federal funding to aid in rapid expansion of the IPM program to many of the area farmers. A carefully designed program to initiate the new strategy along with supervision until the farmers are confident and competent to apply it would improve the acceptance of the program.

This technical assistance is being provided to accelerate realization of the potential benefits of this program. The extension of this IPM program is discussed in detail later in this report (the Trans-Pecos Program).

V. EAST TEXAS PROGRAM

This East Texas Region has a history of heavy infestations of boll weevils, bollworms-budworms, cotton fleahoppers, and thrips. However, until the mid 1960's, systematic application of insecticide every 5 to 7 days provided a degree of insurance and successfully controlled cotton pests. The development of resistance in insects to insecticides resulted in loss of effective control with the traditional insect control program. Loss of ability to control insects with traditional practices resulted primarily from increasing resistance of the tobacco budworm to phosphate insecticides. Sterling and Haney showed that resistance had developed to the point in 1969 that control failures were the rule in Texas Department of Corrections farms. A new integrated pest management program was developed by the Texas Department of Corrections (TDC) and Texas Agricultural Experiment Station for TDC farms (Sterling and Haney).

PROGRAM CHARACTERISTICS

East Texas program consisted of several new practices designed to complement each other. Initially, the boll weevil diapause control program was started in September to reduce the number of weevils leaving the cotton field to overwinter. Periodic application of malathion or methyl parathion (usually every 10 days) was sufficient to reduce boll weevil numbers to a level so that spring insecticidal control measures were not needed (Sterling and Haney). Without early season insecticide application for the boll weevil, beneficial insects and spiders were conserved to help with natural regulation of all cotton pests.

A second practice introduced is the application of low dosages of insecticides for fleahopper during the first three weeks of fruiting (Sterling and Haney). However, application was initiated only if damage levels exceeded 35 to 50 per 100 plant terminals. This was determined by a scientific sampling procedure utilizing scouts to sample fleahopper count. The fleahopper is more sensitive to many insecticides than most beneficials, therefore the lower dosages were designed to reduce fleahopper numbers while maximizing the conservation of the beneficial insects.

The TDC also raised the treatment level for bollworm-tobacco budworm from 5 percent damaged squares to 15 percent damaged squares. By tolerating up to 15 percent damaged squares, premature insecticide applications were not made. Again, beneficials were conserved whenever insecticides were found to be unnecessary (Sterling and Haney).

These three practices involved a direct application of insecticides. However, the use of trained scouts and cultural practices of early crop maturity, harvest and crop residue destruction are an intergral part of the pest management practices of the TDC (Casey, et.al.).

USERS AND LOCATION

Cotton producers in East Texas were experiencing decreasing yield and rapidly increasing insecticide costs. The TDC and the Texas

Agricultural Experiment Station developed an integrated pest management program for the TDC farms because of their large acreage of cotton and the relative isolation of these acres from other cotton producers. This minimized effects other producer actions would have on the program being applied to the TDC.

Due to the number of farms and the differences in production characteristics, the TDC farms were divided into two basic regions of study. Farms of one region follow the Trinity River while farms in the other region are close to the Brazos River. Acres of cotton in each of these river basins from 1968 to 1972, are presented in Table D-19. The farming operations, yields, and pesticide use records of the TDC cotton production provide the data used to evaluate this pest management program (Casey, et.al.).

Table D-19. Acres of cotton produced by the Texas Department of Corrections, 1968-1972[a]

Year	Brazos River Area	Trinity River Area
1968	4,136	2,177
1969	3,408	643
1970	3,878	1,730
1971	3,891	1,848
1972	3,886	1,871

[a] Source (Casey, et.al.).

This means the principal user of the IPM program since the fall of 1970 is the TDC. With adoption of the IPM program by the TDC, there is evidence that other regional producers are adopting a similar one. However, there is no organized concentrated effort to provide education and assistance necessary to bring about rapid adoption.

ASSESSMENT

Production data from the TDC farms included yields, farming operations, and pest control before and after imposition of the integrated pest management program. A four year period was studied, two with an IPM program and two with traditional systematic insecticide treatment system (Casey, et.al.). A single year analysis was not satisfactory because the fall diapause program significantly influenced insecticide applications the following year. Yields and insecticide use data were available by year from the TDC. These records were used to develop an annual estimate of yield and pesticide use in the period preceeding the IPM program and the period after the IPM program.

The IPM program was initiated in the fall of 1970, therefore the traditional system applies to 1968-1970 while the IPM program applies to 1970-1972 operations.

Biological effectiveness

In the three years immediately preceeding the beginning of the IPM program, yields were steadily declining. Reductions reached half of the expected yields based on historical performance (Sterling and Haney). A major contribution of the new strategy was the indicated increase in cotton yield associated with natural biological regulation of cotton pests that have developed resistance to insecticides.

In the Trinity River area, from 1968-1970, the mean yield per acre was 348 pounds per acre (Casey, et.al.). After initiating the IPM program in 1970, the average yields increased to 510 pounds per acre on the same acres. About 50 percent or 80 pounds of lint increase is attributable to the IPM program (Casey, et.al.). Similarly, in the Brazos River Area, yields were 229 pounds of lint per acre from 1968-1970 compared to 345 pounds in 1971-1972. As above, by adjusting for general trends some 50 percent or 60 pounds of lint increase per acre can be attributable to the IPM program (Casey, et.al.).

The opportunity for increased yield holds significant implications for yield increases in counties surrounding the TDC farms. The per acre results on the TDC farms were expanded to all cotton acres in the region to develop estimates of increased output that could be affected if cotton producers of the area adopted the program. In the area surrounding the Trinity River Area TDC farms, approximately 53,700 acres are devoted to cotton annually (Texas Crop Reporting Service). It is estimated that output would increase by over 8,500 bales in the Trinity River Area if the IPM program was adopted area wide (Casey, et.al.). In the Brazos River area, 160,000 acres of cotton are grown and outputs would be expected to increase by about 18,500 bales with the IPM program (Texas Crop Reporting Service).

The new program was designed to reduce the amount of chemical applied in order that beneficials could help in the natural regulation of pests. Under the traditional system, a systematic application of malathion or methyl parathion was used in August and September to control tobacco budworm and bollworm (Sterling and Haney). Under the IPM program, this practice was terminated and using traditional definitions, a higher economic threshold was permitted before insecticides were applied to control these pests. However, since these chemicals were reduced and residue was not destroyed until October, the potential for increased boll weevil overwintering increased. A diapause program of methyl parathion in late August along with early crop residue destruction has successfully decreased the number of boll weevil overwintering. By decreasing the boll weevil numbers in the fall, little or no control is required the following year, thus allowing the conservation of desired beneficials.

By increasing the damage level before applying insecticides and using low levels of insecticide, recent production inputs and outputs strongly indicate increased beneficials have been satisfactory in controlling the tobacco budworm and bollworms.

Costs and returns

The IPM program developed for the TDC is for a particular pest complex problem and public support was directed primarily to the TDC. With an evaluation available on this program, economic implications appropriately emphasize the user or producer.

Regarding implementation, the pest management program was developed by the Texas Agricultural Experiment Station through research funded by Cotton, Incorporated. By not considering the research component, implementation costs were essentially zero since the TDC simply began applying a research developed program.

Program costs: Program costs not supported by the user are limited principally to consultation and interaction with entomologists of the Texas Agricultural Experiment Station. It is estimated that 0.05 SMY was allocated to this program in 1970, 1971 and 1972 and 0.25 in 1973. At $40,000 per year for an SMY, this places this IPM program cost against public funds at approximately $2,000 per year. It is, however, for limited cotton acreage and one institutional producer and does not include any of the research development effort.

Producer: Strictly from a producer's viewpoint, costs to the TDC include $5 per acre for a scout, costs of the insecticides, and normal production inputs. Table D-20 shows producer cost and returns, with and without the IPM program, in the two areas of the TDC farms (Casey, et.al.).

Data in Table D-20 indicate that the producer would clearly be in an economically favorable position under the IPM system. The cotton scout is the only additional cost of the new program but this

Table D-20. Expected per acre costs and returns associated with cotton production using traditional pest control techniques and an IPM program and in Trinity River Area and Brazos River area[a]

	Brazos River Area			Trinity River Area		
Cost and returns	Traditional	IPM program	Difference	Traditional	IPM program	Difference
Returns	90.95[b]	136.95[c]	46.00[d]	138.00[e]	202.50[f]	64.50[g]
Insecticide cost	13.31	3.51	-9.80	9.82	4.06	-5.76
Cotton scout	5.00	5.00	0.0	5.00	5.00	0.0
Other variable costs	72.97	83.55	10.58	97.00	98.82	1.02
Total variable costs	86.28	87.06	.78	107.62	102.88	-4.74
Fixed costs	13.85	13.85	0	13.85	17.85	0.0
Total costs	105.13	105.91	.78	126.47	121.73	-4.74
Net returns	-14.18	31.04	45.22[h]	11.53	80.77	69.24[i]

[a] Source (Casey, et.al.).

[b] Based on yield of 510 pounds of lint per acre and 35 cents per pound of lint cotton price.

[c] Based on yield of 348 pounds of lint per acre and 35 cents per pound of lint cotton price.

[d] Only 50 percent of the yield increase is attributed to the IPM program.

[e] Based on yield of 345 pounds of lint per acre and 35 cents per pound of lint cotton price.

[f] Based on yield of 229 pounds of lint per acre and 35 cents per pound of lint cotton price.

[g] Only 50 percent of the yield increase is attributable to the IPM program.

[h] With 50 percent of the yield increase attributable to the IPM program, $22.61 per acre net return increase is all that can be attributed to the IPM project.

[i] With 50 percent of the yield increase attributable to the IPM program, $34.62 per acre net return increase is all that can be attributed to the IPM project.

cost is offset by the reduction in insecticide costs. Thus, there are no significant differences in production costs between the traditional pest control strategy and IPM program. This means the yield increase associated with the IPM program, as compared to the traditional pest control tactics, is increased net returns to the producer; i.e., 60 pounds of lint in the Brazos River area and 80 pounds of lint in the Trinity River Area (Casey, et.al.). Based on 1970 input prices and 35 cents per pound for cotton, the increased net returns associated with the IPM program are an estimated $22.61 per acre in the Brazos River area and $34.62 per acre in the Trinity River Area.

Environmental implications

A major modification in expected operating inputs with the IPM program compared to traditional pest control tactics is the amount of insecticides applied per acre. Tables D-21 and D-22 compare the pounds of alternative insecticides applied per acre in the Trinity River and Brazos River areas, respectively (Casey, et.al.).

For the Trinity River area, using the IPM program, the quantity of insecticide applied was reduced almost 50 percent, from 10.96 pounds to 5.55 pounds per acre (Casey, et.al.). This reduction was due to the elimination of toxaphene and the reduction in methyl parathion used. Dylox was added for the fleahopper control when scouting indicated control was necessary. Malathion for diapause was increased from 2.34

Table D-21. A comparison of chemicals applied with traditional practices and an IPM program: Trinity River area section of the Texas Department of Corrections cotton farms[a]

		Pest management program[b]	
Pesticide	Unit	Traditional 1968-1970	IPM 1970-1972
Toxaphene	lbs/ac	1.70	0.0
Methyl parathion	lbs/ac	6.69	0.22
Defoliant	lbs/ac	0.05	0.48
Malathion-diapause	lbs/ac	2.34	3.29
Malathion	lbs/ac	.18	0.0
Endrin	lbs/ac	0.0	0.26
Dylox	lbs/ac	0.0	1.30
Total pesticides	lbs/ac	10.96	5.55

[a] Source (Casey, et.al.).

[b] All totals based on a weighted average of pounds applied per acre on all northern sections Texas Department of Corrections cotton farms.

Table D-22. A comparison of chemicals applied with traditional practices and an IPM program, Brazos River area section of the Texas Department of Corrections cotton farms[a]

Pesticide	Units	Pest management program[b]	
		Traditional 1968-1970	IPM 1970-1972
Toxaphene	lbs/ac	1.26	0.0
Methyl parathion	lbs/ac	9.41	0.72
Malathion	lbs/ac	.11	0.0
Defoliant	lbs/ac	.58	.24
Malathion-diapause	lbs/ac	1.58	1.01
Methyl parathion-diapause	lbs/ac	0.0	4.08
Dylox	lbs/ac	0.0	0.02
Endrin	lbs/ac	0.0	0.35
Total pesticides	lbs/ac	12.94	6.42

[a] Source (Casey, et.al.).

[b] All totals based on a weighted average of pounds applied per acre on all southern sections, Texas Department of Corrections cotton farms.

pounds to 3.29 pounds per acre as a stepped up fall diapause program was an integral part of the IPM program (Casey, et.al.).

Table D-22 shows similar insecticide inputs under both programs in the Brazos River area. Total pounds of insecticides per acre decreased by slightly over 50 percent from 12.94 pounds to 6.42 pounds per acre by using the IPM program (Casey, et.al.). Similar to the Trinity River area, toxaphene was eliminated and methyl parathion greatly reduced. Dylox was added in small amounts as fleahopper control was minimal. Only methyl parathion was increased significantly in the IPM program. Methyl parathion is a part of the fall diapause program.

Expanding these per acre insecticide reduction rates to the surrounding areas, it is estimated that approximately 300,000 less pounds of insecticides would be introduced into the environment with adoption of the IPM program throughout the Trinity River area (Casey, et.al.). In the Brazos River area, it is expected that use of IPM program would reduce the quantity of insecticides used by over one million pounds. Tables D-23 and D-24 show the change in each of the insecticides that could be expected if the IPM program was used on all cotton acres in the Trinity and Brazos River area.

PROGRAM FEASIBILITY AND EXPANSION

In many areas, as was the case on the TDC farm, the use of insecticides has evolved to a strategy characterized by the automatic application of chemicals at predetermined intervals. This application

Table D-23. Estimated insecticide use with the IPM program and the traditional insect control technique in the Brazos River area[a]

Chemical	Unit	Pest management program Traditional 1968-1970	 IPM 1970-1972	Difference
		------------------	1,000	--------------
Toxaphene	lbs	202.7	0	202.7
Parathion	lbs	1,514.1	115.8	-1,398.3
Malathion	lbs	17.7	0	-17.7
Defoliant	lbs	93.3	38.6	-54.7
Malathion-diapause	lbs	254.2	162.5	-91.7
Endrin	lbs	0.0	56.3	56.3
Dylox	lbs	0.0	3.2	3.2
Methyl parathion-diapause	lbs	0.0	656.5	656.5
Total	lbs	2,082.0	1,032.9	-1,049.1

[a] Source (Casey, et.al.).

Table D-24. Estimated insecticide use with the IPM program and traditional insect control technique in the Trinity River area[a]

		Pest management program		
Chemical	Unit	Traditional 1968-1970	IPM 1970-1972	Difference
		1,000		
Toxaphene	lbs	91.3	0.0	-91.3
Methyl parathion	lbs	359.3	11.8	-347.5
Defoliant	lbs	2.7	25.8	23.1
Malathion-diapause	lbs	125.7	176.7	51.0
Malathion	lbs	9.7	0.0	-9.7
Endrin	lbs	0.0	13.9	13.9
Dylox	lbs	0.0	69.8	68.8
Totals	lbs	588.6	298.0	-290.5

[a] Source (Casey, et.al.).

is often carried out regardless of the size and concentration of the pest populations at the time. Increased insect resistance is often met by increased insecticide dosages to obtain insect control; the net effect is less control and more resistance of the pest to insecticides. The TDC has demonstrated a feasible alternative to this dilemna, while meeting society's priority of introducing less insecticide into the environment. The analysis indicates that IPM is a viable program and with its implementation on the TDC, it has been demonstrated that the tobacco budworm could be managed without exclusive reliance on insecticides (Casey, et.al.). Implications of this study are that if this IPM program were extended to the 214,600 cotton acres in the region, output would increase by 27,000 bales, insecticides applied would be reduced by 1.3 million pounds (50 percent) and producer net returns would increase over $6 million (Casey, et.al.). Areas with similar production charactersitics provide possibilities for this IPM program to be expanded to all cotton production in East Texas. Some producers already have adopted a similar or comparable program and it is expected that greater success for all producers will be realized as more acres move under an IPM program system.

Across Texas and the United States production characteristics vary significantly due primarily to different climatic conditions over a large area. However, there are opportunities to use a pest management program comparable to the system developed for the TDC in many cotton producing areas. Consideration must be given to the specific pests and timing of various production stages.

A major limitation of this and many IPM programs is that it is designed for large areas. Individual producers, particularly on small acreage, could expect only limited to no success as they will be affected by neighbors who do not practice IPM.

This means that an education and assistance program for farmers, funded by society, is absolutely essential to facilitate adoption of the East Texas program (an overall integrated pest management program) in the East Texas region and other regions that have the bollworm, boll weevil, budworm pest complex and emerging resistance of the tobacco budworm. Federal funding of demonstration on all farms in a wide area would be expected to accelerate adoption of the IPM program.

TEXAS COTTON INSECT MANAGEMENT PROGRAM

The Texas cotton insect management program is a part of a beltwide cotton pest management demonstration and education program. Funds from the U.S. Department of Agriculture were made available for this multi-state program with the Cooperative Extension Service of each participating state responsible for implementing and conducting the program.

For the Texas programs, funding was provided in April, 1972. This meant that the program was initiated during the production season. This was a severe restriction on the 1972 program. In 1973, the program and producer cooperation began with the growing season.

The goal and objectives of the Texas cotton insect management programs were to familiarize the growers with pest management principles by: a) educational activities through personal and news media contact to explain economic damage levels, b) promote the use of field scouting by the grower to provide reliable insect count information that could be directly related to Texas insect control guide, c) to reduce the indiscriminate use of pesticides, d) to inform the growers of the value of beneficial insects in suppressing bollworm-budworm populations, e) instigate and maintain programs for the diapause control of the boll weevil and pink bollworm, f) provide immediate answers to grower insect control questions, g) maintain complete computer stored records on insect population numbers, insecticide use and farming practices, and use this information to observe possible trends that may aid in promoting better pest management, and h) provide a method of evaluating economic impact and producer attitude of the program (Frisbie, et.al., 1972 b).

Operation of the Texas cotton insect management programs is directed by a Texas Agricultural Extension Service statewide coordinator and project leader. The responsibilities of the statewide leader are to improve the efficiency of the program and provide leadership, guidance and consultation to each area program leader (Frisbie, et.al., 1972 b).

For each area program, the county extension entomologist is responsible for training and supervising cotton field scouts. In scouting a cotton field, the scouts are trained to appraise pest and beneficial insect species, record plant growth conditions, chemical use, and the plant growth situation in fields adjacent to the field being scouted. Findings of the scout are reported to the producer and county extension entomologist. The scout does not suggest specific insecticides for insect control. However, the producer may seek advice from the county extension entomologist. The county extension entomologist reviews scout reports and when potentially damaging pest populations are present, may call or visit with the producer. In this way, unnecessary applications of insecticides are discouraged when pest populations are not at economically damaging levels (Frisbie, et.al., 1972 b).

Producer responsibilities in the Texas programs include being aware of (1) what constitutes damaging pest populations, (2) the advantage of beneficial insects and cultural control measures, (3) the disadvantage of poorly timed calendar-based insecticide treatments and (4) communication with the county extension entomologist when he has a question about insect problems (Frisbie, et.al., 1972 b).

The Texas programs have operated for part of 1972, all of 1973-74 and are in process for 1975. This evaluation covers 1972 and 1973.

There are four cotton insect management programs in Texas: (1) Rio Grande Valley, (2) Blacklands, (3) Trans-Pecos, and (4) Frio County. Each of these programs is considered, by year, with an overall evaluation of the program for 1972-73. Implementation costs of each program are discussed in the 1972 evaluation. Statewide coordination and leadership costs are considered separately at the conclusion of the Frio County evaluation.

Regarding evaluation, scientists involved in the program have done an excellent job of identifying important characteristics of the programs relative to yield, insecticide used, and economic implications to the producer, particularly in 1973 (Frisbie, et.al., 1972 b, 1973 b). Data from these reports as well as much of the analysis, were widely used in this evaluation.

Producer organizations are an important part of the cotton insect management programs in Texas. When funding for the programs was assured, information relative to the program was provided through the producer organizations. The producers were informed as to costs per acre of the program to them if they chose to participate. The program in each of the four program regions was open to all producers with no acreage restrictions in 1972.

The cotton insect management programs, with funds provided through a cooperative agreement with the U.S.D.A., in all regions of Texas in 1972 began during the growing season. The late start, due to the date funding was provided, was a severe limitation to the 1972 programs. In addition, as with the initiation of any large program, some data needed for a complete economic and environmental evaluation were not collected. Most significant among these was lack of a control group in 1972. Since data are not available for a control group in 1972, a comparison of program participants and non-participants is not possible, therefore, definite conclusions relative to the 1972 program effectiveness are most difficult. In fact, it may be appropriate to include the 1972 program as part of implementation, although that is not done in this evaluation.

The 1973 programs were evaluated in detail with a control group. An even more complete program evaluation is planned for the 1974 programs including analysis of producer attitude adjustments. A rural sociologist is participating in this phase of the 1974 analysis.

I. RIO GRANDE VALLEY PROGRAM

Approximately 300,000 acres of cotton are produced in this region. Insects are a major problem in cotton production, and consequently, insecticide use per acre of cotton is among the largest in the U.S. Most major cotton pests are present in the area and include the fleahopper, boll weevil, bollworm and tobacco budworm (Frisbie, et.al, 1972 b). Control of the early season insects and overwintering boll weevils with insecticide destroys naturally occuring predators and parasites. Without the beneficial species, outbreaks of the bollworm-budworm complex usually occur. A major complicating factor is the high degree of resistance that the tobacco budworm has developed and inability of producers to control it when outbreaks occur (Frisbie, et.al., 1972 b).

A further aggravation of the insect problem is traditional cotton production techniques. Farmers, in their efforts to derive high per acre yields, plant mostly long season indeterminate cotton varieties, often apply excessive quantities of nitrogen and irrigation water late in the season. This delays maturity, extends the growing season and provides excellent habitat for insects. In addition, the weather pattern is such that the incidence of rainfall increases significantly in late summer and early fall, hence, the harvest period is often delayed. This means an increased population of overwintering boll weevils and intensifies the insect problem the following year (Frisbie, et.al., 1972 b). Due to all these factors, the Rio Grande Valley is an excellent area for a regional integrated pest management program.

PROGRAM CHARACTERISTICS

Funds for the Rio Grande Valley program became available in April, 1972. Growers were contacted by the Cotton and Grain Producers Association with 19,830 acres of cotton selected for inclusion in the program by the end of April, 1972 (Frisbie, et.al., 1972 b). The cost of the program to growers was 75 cents per acre (approximately one-half the cost of field scouts).

With the many complex relationships relative to cotton production in the Rio Grande Valley, this program through the county entomologist is approaching the recommendation stage for an overall production system. The specific program goals for this region are: (1) to furnish cooperating producers the necessary information on pests, beneficials and damage levels in order to allow them to better evaluate what control measures are necessary, (2) to educate producers in pest management concepts,(3) to emphasize the importance of field scouting in determining the need for pest control and (4) to collect data on pests and beneficial population trends under varying habitats, cotton varieties, weather conditions, farming practices and pesticide use patterns (Frisbie, et.al., 1972 b).

To carry out these goals, six scout teams (two men to a team) were hired to scout 19,830 acres of cotton in 1972. This means each team scouted 3,305 acres or 96.5 fields on the average (Frisbie, et.al., 1972 b). The scouting technique adopted involved scouting 25 squares and 25 plants at each of four field locations, with fields of less than 40 acres scouted in only two locations.

The data from scouting is reported to the producer and the county extension entomologist. Data on surrounding vegetation, cotton variety, planting pattern, acres of cotton and planting date was obtained for a permanent record (Frisbie, et.al., 1972 b). Field reports go from the county extension entomologist to computer cards for data processing.

Changes in 1973, as compared to 1972 program, indicate reducing scouted cotton acreage from 19,830 to 15,632 and beginning of field inspection three weeks earlier (Frisbie, et.al., 1972b). In 1973, average acres of cotton per scout was 2,605 and each field was inspected weekly except when weather conditions were prohibitive. Each field was checked an average of 16.3 times during the season (Frisbie, et.al., 1973 b). During 1973, scouts and extension entomologists made more personal contact with cooperating producers.

USERS AND LOCATION

The Rio Grande Valley includes Hidalgo, Willacy and Cameron Counties. There are over 3,000 producers in the region, with 90 cooperative growers in 1972 and 77 in 1973 (Frisbie, et.al., 1972 b; 1973 b). Emphasizing 1973, due to data availability, the program included 4,149 acres of cotton and 36 producers in Cameron county, 10,196 acres of cotton and 37 producers in Hidalgo county and 1,283 acres of cotton and four producers in Willacy county (Frisbie, et.al., 1973 b). Average acres per producer in the program were 203 for the region (115 in Cameron county, 276 in Hidalgo county and 322 in Willacy county).

Data relative to total acres of cotton grown by each producer, or even total acres of cropland per producer, are not readily available. It has been recommended that this information be obtained from cooperating growers in the future. Further, time constraints of the county extension entomologist within the realm of this study preclude a frequency table of cooperating producers by acres of cotton in the program. However, to estimate yield, a stratified sample of 22 growers (cooperators and non-participating producers) was used. The sample was drawn so that both groups had comparable managerial ability. From this sample the number of producers for alternative frequencies of cotton acreage are given in Table D-25.

Table D-25. Distribution of a sample of participating and non-participating cotton producers by acres of cotton produced, Rio Grande Valley, 1973[a]

Cotton acreage distribution	Number of producers	
	Participating	Non-participating
0 - 50	4	1
51 - 200	11	7
201 and greater	7	14

[a] Source (Frisbie, 1974 c).

For these samples of producers, the implication is that the Rio Grande Valley program services the average to smaller rather than larger cotton producer. However, simply based on the sample, such a conclusion is difficult. Traditionally, new technology is adopted more rapidly by the better managers who generally operate the larger farms. With demonstration by the better managers that some new technology is operational and can improve the firm's net income situation, it is adopted over time by other managers in the region.

Table D-26 shows the distribution of all cropland acres by size in the Rio Grande Valley. Approximately one half of the total farms are less than 50 acres but only about 20 percent of the sample farms were in the largest size classification. The greatest proportion of participators are in the average size farm (i.e., 50-200 acres). Cooperating sample producers in this class are 50 percent of those sampled, while only about 20-25 percent of all cropland acres are on farms of this size.

ASSESSMENT -- 1972

A complete assessment of the program in 1972 is not possible due to lack of a control group. Furthermore, effectiveness of the program was severely restricted by the late funding date and in turn late program starting date.

Table D-26. Distribution of farms size by acres produced in the Rio Grande Valley[a]

Cropland acreage distribution	Number of farms
0 - 49	4,046
50 - 100	986
100 - 179	1,041
180 - 259	591
260 and greater	1,747

[a] Source (U.S. Department of Commerce).

Biological effectiveness

Without a control group, little can be concluded. Relative to yield, the average lint yield per acre for participating growers was 496 pounds compared to 1972 lint yield across the three counties on irrigated land of 485 pounds (Frisbie, 1972 a). This is not sufficient information to draw definite conclusions, but indicates that some yield advantage may be associated with the program.

This area experienced tremendous pressure from bollworms and tobacco budworms in 1972 due to a mild winter in 1971, early spraying for boll weevils and fleahoppers, and low numbers of beneficials after May even in untreated fields (Frisbie, et.al., 1972 b). Insect populations exceeded economic threshold levels, as identified in Texas research, an average 4.97 times (Frisbie, 1972 a). Cooperating growers treated an average of 10.41 times. Total number of treatments is near the expected average for the region.

The lack of beneficial species after May resulted in spraying for attempted control of bollworm and budworm. Some of the bollworm-budworm problem may be attributable to insect control by spraying that began before this program was initiated. The grower, in effect, largely predetermined his pest control strategy before the program began. Much of the 1972 program effort was expended in developing producer confidence and likely was not very effective in increasing yields or taking full advantage of natural biological control.

Costs and returns

With regard to economic implications of the 1972 program, the analysis is limited to identifying implementation costs, operation and overhead program costs and insect control costs of cooperating growers. Implementation: Time and effort by the Texas Agricultural Extension Service with inputs by the Texas Agricultural Experiment Station began several months before the program was funded. However, most of these implementation costs are identified at the state level (reported after Frio County). Estimated implementation costs for the Rio Grande Valley program are presented in Table D-27.

Table D-27. Estimated implementation costs of the Rio Grande Valley Scout Program[a]

Item	Source of funds		
	Grant[b]	TAEX[c]	Total
	---------------- dollars	----------------	
Mapping	1,500	2,000	3,500
Grower contact	2,000	1,500	3,500
Recruitment	1,000	2,000	3,000
Scout training	1,000	2,000	3,000
Total	5,500	7,500	13,000

[a] Source (Frisbie, 1974 a).

[b] Cooperative funds from U.S. Department of Agriculture

[c] Texas Agricultural Extension Service

Implementation costs of this regional program were an estimated $13,000 of which the Texas Agricultural Extension Service incurred $7,500 and the Federal Cooperative Agreement funds covered the other $5,500.

Program costs: Cost of the 1972 Rio Grande Valley program were incurred by the Federal Pest Management Grant Funds, Texas Agricultural Extension Service and cooperating growers. The 1972 program costs, by source of funds, are presented in Table D-28 and is for the period of May 17, 1972 through December 31, 1972.

Total 1972 program cost in the Rio Grande Valley was $35,386, and do not include implementation costs or costs allocated to the state level (reported after Frio County evaluation). Of this, 49 percent was paid from federal grant funds ($17,231), 24 percent by the Texas Agricultural Extension Service ($8,655) and, 27 percent by participating growers ($9,500). This indicates that total program costs per acre of cotton in the program was $2.06. This per acre cost is low relative to the charge by private consultants and likely suggests an over obligation of acres for the number of scouts.

Producer: Based on a sample of 23 growers, including 4,767 acres, the participating grower treated for insects an average of 10.41 times per acre applying 1.66 pounds of active ingredients each time (Frisbie, 1972 a). This means a total of 17.28 pounds of chemical was applied per acre for insect control. The vast majority of the treatments was for boll weevil and bollworm-budworm complex. Total producer costs per acre for materials and application were an estimated $28.78. There was no control group in 1972, hence, a comparison with the typical producer in the region is not attempted. They are likely very comparable.

Environmental implications

Application of over 17 pounds of chemical per acre to cotton on the sample 4,767 acres gives a total insecticide load in the environ-

Table D-28. Rio Grande Valley program cost by source of funds, 1972[a]

Item	Unit	Cost per unit	No. of units	Total cost	Source of funds Grant[b]	TAEX[c]	Producer[d]
		dollars		------------	------------ dollars	------------	------------
Salary							
County Extension Entomologist	man	8,000	1	8,000	8,000	0	0
Scout	man	1,417	12	17,002	8,501	1,140	7,361
Clerical	program	1,020	1	1,020	1,020	0	0
Travel							
County Extension Entomologist	program	8,514	1	8,514	1,089	7,425	0
Scout	program	5,030	1	5,030	3,382	0	1,648
Supplies, misc. and incidentals	program	1,320	1	1,320	739	90	491
Less implementation costs	program	5,500	1	-5,500	-5,500	0	0
Total				35,386	17,231	8,655	9,500

[a] Source (Frisbie, 1973 a).

[b] Cooperative funds from U.S. Department of Agriculture

[c] Texas Agricultural Extension Service

[d] Producer cost was 75 cents per acre

ment of over 81,000 pounds. Extending this to the 19,830 acres of participating growers yields over 337,000 pounds of insecticide. Since the 17 pounds per acre of chemical for insect control is expected on all irrigated cotton acres in the region for 1972, total pounds of chemical on irrigated cotton for insect control is estimated to be 3,850,000 pounds based on 225,000 acres of irrigated cotton (Texas Crop Reporting Service).

The only indication of program effectiveness was in a questionnaire completed by a sample of 33 participating growers. In this questionnaire, 39 percent replied that the program resulted in their saving at least one insecticide application (Frisbie, et.al., 1972 b). Although small and difficult to actually measure, this represents a step in the desired direction.

Effectiveness of the 1972 program can only be superficially considered. In this context, the implication is that the program did not significantly reduce the pesticide load in the environment and there is a need and good opportunity to improve this situation in this area through the federal grant program.

Participating growers evaluation

A most important aspect of a regional program such as the Rio Grande Valley scout program is gaining producer confidence and subtly altering traditional attitudes relative to pest management and overall production strategies. To develop some indication of producer reaction to the 1972 program, 33 participating growers, representing a cross section of all participating growers, were asked to complete a questionnaire (Frisbie, et.al., 1972 b). Many of the comments of producers were anticipated such as (1) fields should be checked more thoroughly, (2) scouts should have more direct contact with growers, (3) scouts need more training and (4) the survey program should start earlier (Frisbie, et.al., 1972 b). Results of the questionnaire also indicated one of the survey teams failed to gain the confidence of a substantial number of participating growers. As indicated, most of the comments were anticipated and changes already planned for the 1973 program.

On the more positive side, a summary of producer reaction of the Rio Grande Valley program from the questionnaire is (1) 71 percent felt the insect reports were reliable, (2) 74 percent indicated that the survey was of benefit to them in their pest control practices, (3) 39 percent said the program saved them at least one insecticide application and (4) 59 percent replied that the program provided timely information to control infestations (Frisbie, et.al., 1972 b).

Program visibility was accomplished reasonably well through (1) three television programs, (2) presentations at growers meetings, (3) daily insect reports aired on television and radio, (4) weekly insect reports sent to growers, county extension agents, chemical formulators, private entomologists and the news media, and (5) individual grower contact (Frisbie, et.al., 1972 b). Through this type of service, there is immediate and direct program spinoff to non-participating growers that cannot easily be identified or measured.

In summary relative to the Rio Grande Valley scout program, the lack of a control group makes a definitive conclusion difficult and the late funding date severely limited potential effectiveness. The 1972 program was successful in gaining producer confidence and was a useful learning process to identify some key factors to a successful program. Among these was the strong indication that producer confidence was directly related to the amount of scout contact with the producer. Again, there is a real inclination to include all of 1972 in implementation and consider an evaluation for only 1973.

ASSESSMENT -- 1973

For the 1973 Rio Grande scout program, emphasis was placed on evaluation. Of primary importance was the establishment of a control group.

Much care was exercised to make the control group as comparable as possible to the participating producers. For example, there was an attempt to have producers in both groups that used the same variety, irrigation practices and had similar farm management capabilities (Frisbie, et.al., 1973 b). Data were collected for 22 participating growers and 22 non-participating growers. These data provide the basis for much of the analysis.

Biological effectiveness

Due to rain, the 1973 cotton crop was 2 to 3 weeks late (Frisbie, et.al., 1973 b). Fleahopper populations in many Rio Grande Valley areas were extremely high with growers treating 1 to 2 times for control. The boll weevil infestation reached economically damaging levels in the middle of June, hence, growers were faced with beginning a spray program at an early date (Frisbie, et.al., 1973 b). More rain from June 20 to June 27 further delayed the 1973 crop. This can be interpreted to mean that 1973 was not a so-called "good" cotton year in the Rio Grande Valley.

Using data from the 22 participating growers and 22 non-participating growers, average lint yield in 1973 was 504 pounds and 403 pounds, respectively (Frisbie, et.al., 1973 b). The 25 percent increase in lint production per acre for participating producers, compared to non-participating producers, indicates the program was very successful in improving lint output per acre.

To aid in the interpretation of lint yield differences, a measure of standard deviation was calculated for participators and non-participators in the Rio Grande Valley. The computed values were 100 and 103 for participators and non-participators,respectively. This indicates that there is no significant difference in yield variation between the two groups. The variation in yield was slightly less for participating producers indicating that yields were more clustered around the 504 pound average than at the 403 pound average for non-participators.

Costs and returns

Economics of the Rio Grande Valley program is considered from the cost of conducting the program and implications of the program on individual producer production practices and corresponding costs and returns.

Program costs: As in 1972, the program costs were incurred primarily by the Federal Pest Management Grant Funds, Texas Agricultural Extension Service and cooperative producers. Expenditure for the 1973 calendar year of the Rio Grande Valley scout program, by type and source of funds, are given in Table D-29. Total cost, not including costs allocated to state coordination, were $48,150 in 1973 (Frisbie, 1974 b). Of this the Federal Grant Funds paid $36,792 (76 percent), $7,425 by the Texas Agricultural Extension Service (16 percent), and $3,933 by cooperating producers (8 percent). This means the cost per acre of cotton in the program was about $3.00, as compared to $2.06 in 1972. The indicated increase in program effectiveness in 1973 justifies the decision to scout more intensely and have more grower contact even though the cost is over one dollar per acre higher. An objective of the program is to have an effect, not maximize the acres scouted.

Producer: Participating producers incurred a 75 cents per acre program charge. To evaluate overall economic implications of cooperating growers, relative to non-participating growers, data from the two sample groups were used. Producers in the control sample were selected that had comparable managerial capabilities as the sample of participating growers

Table D-29. Rio Grande Valley program cost by source of funds, 1973[a]

Item	Unit	Cost per unit	No. of units	Total cost	Source of funds: Grant[b]	TAEX[c]	Producer[d]
		dollars		----------- dollars	-----------	-----------	-----------
Salary							
County Extension entomologist	man	12,744	1	12,744	12,744	0	0
Scouts	man	1,564	12	18,771	15,112	0	3,659
Clerical	program	1,754	1	1,754	1,754	0	0
Travel							
County Extension entomologist	program	9,073	1	9,073	1,648	7,425	0
Scout	program	4,552	1	4,552	4,552	0	0
Supplies, misc and incidentals	program	1,256	1	1,256	982		274
Total				48,150	36,792	7,425	3,933

[a] Source (Frisbie, 1974 b).

[b] Cooperative funds from U.S. Department of Agriculture

[c] Texas Agricultural Extension Service

[d] Producer cost was 75 cents per acre

The data relative to production inputs and yield were processed by applying an Enterprise Budget Generator computer program (Frisbie, et.al., 1973 b). The results for each group of producers are summarized in Table D-30.

The larger yield of participating growers resulted in their gross revenue per acre being $65.15 more than for non-participating growers. The participating grower did incur more costs for inputs, primarily insecticide and harvest costs, for the larger output ($207.91 total cost of production for participating growers compared to $198.07 for non-participating growers). The difference in terms of net revenue per acre was $55.31 more for participating growers ($104.49 compared to $49.18). Analysis of the data from the two sample groups of growers strongly indicates the Rio Grande Valley program has contributed to increased yields and net returns for participating growers.

Environmental implications

Insecticide use of participating growers was higher in number of applications and pounds used than for non-participating growers, based on data from the two sample groups. Participating growers applied an average of 12.1 applications of insecticide per acre. Pounds applied per application were 1.93, hence a total of 23.4 pounds of insecticide per acre was applied by participating growers. Non-participating growers applied 2.02 pounds of insecticide an average of 10.4 times for a total annual per acre application of 21 pounds (Frisbie, et.al., 1973 b).

Table D-30. A comparison of expected per acre costs and returns for participating and non-participating irrigated cotton producers in the Rio Grande Valley program, 1973[a]

Item	Unit	Price or cost per unit	Participating growers Quantity	Participating growers Value or cost	Non-participating growers Quantity	Non-participating growers Value or cost
Returns						
Lint	lb	0.55	504.0	277.20	403.0	221.65
Seed	ton	80.00	0.44	35.20	0.32	25.60
Total				312.40		247.25
Variable costs						
Preharvest[b]	acre	NA	1	102.18	1	98.66
Harvest[c]	acre	NA	1	38.70	1	33.35
Fixed costs[d]	acre	NA	1	67.03	1	66.06
Total cost	acre	NA	1	207.91	1	198.07
Net returns	acre	NA	1	104.49	1	49.18

[a] Source (Frisbie, et.al., 1973 b). Itemized enterprise budgets were developed using the Enterprise Budget Generator computer program. This analysis does not consider government farm programs.

[b] Production inputs were greater for participating producers for insecticide and machinery.

[c] The difference in harvest cost for the two groups is explained by the yield difference.

[d] A fixed land charge of $35 per acre was included.

This suggests the program in the Lower Rio Grande Valley has not had a real effect on reducing quantity of insecticides used in the region. However, the yield increase of participating growers suggests improved timing of insecticide treatments to reduce damage by insects.

In a questionnaire completed by growers, 16 growers indicated the program saved them at least one insecticide application (most responded from 1 to 3 applications) while 9 indicated no insecticide application savings. This can be interpreted as some initial reductions in insecticide application and although small, it represents a beginning.

A problem in the region that needs to be considered in extensive spraying of any cotton acreage (participant or non-participant) is associated with considerable insecticide drift (Frisbie, et.al., 1973 b). This makes it difficult to preserve beneficial insect populations within the program area. This means action of non-participants can significantly affect participants and, in effect, force them into a treatment situation. Therefore, the implication is that a truly region - wide program including a vast majority of the cotton acreage is needed. As the scout program demonstrates the advantages of integrated pest management programs, it can be anticipated the surrounding producers will begin to incorporate the principles. Evidence presented in the South Texas Program discussed earlier indicate an opportunity for significantly changing the traditional cotton production practices in the Lower Rio Grande Valley with no loss in cotton yield while dramatically reducing the quantity of insecticides used. Continuation of the scout program or a similar type program, is needed to bring about such a regional adjustment. Some advantages of reducing the quantity of insecticides used in the region was discussed in the South Texas Program.

Participating growers evaluation

To obtain growers comments and reaction to the program, a questionnaire was used. Thirty-six of 77 participating growers completed the questionnaire (Frisbie, et.al., 1973 b). This discussion is a summary of the completed questionnaires.

For the 1973 Rio Grande Valley scout program, the growers felt that the cotton insect reports were reliable, delivered promptly and provided timely information to control infestations. This suggests grower confidence in the scouts.

Sixteen growers indicated the program saved them at least one insecticide application. Grower contact is emphasized in the program, but only 18 growers indicated they contacted the county extension entomologist when they had a question while 18 did not. This may be explained by the fact that the county extension entomologist contacted growers when insect problems were found, hence, growers did not have to initiate the contact. Similarly, 19 growers used the "Texas Suggestions for Controlling Cotton Insects" published by the Texas Agricultural Extension Service as compared to 13 that didn't. The 13 may have consulted with the county extension entomologist, however, and with him selected an insect control strategy and hence would not have used the publication directly.

Considering attitude of producers' toward the program, 26 of 36 indicated they would like to see the county extension entomologist more responsible in helping them time their insect control measures. This may be interpreted to mean the producers want the county extension entomologist to make their decisions for them. It would not be advisable to go to far in that direction. More on the positive side, this may indicate a willingness by producers to use the technical assistance that the county extension entomologist can supply. With new information the producer is in a position to make improved pest management decisions.

Twenty-seven said they planned to participate in the 1974 program and one did not plan to participate. Regarding program spinoff, 20 growers responded that they felt their neighbors who were not participating in the program gained some benefit from it; seven growers did not see any spinoff benefits for non-participants. Lastly, 25 indicated a willingness to support the entire scout program at a rate of $1.50 per acre while three did not (Frisbie, et.al., 1973 b).

The above information is based on questionnaires completed by producers. An important gap in this information is the attitude of non-respondants. It would be useful to sample the non-respondants for their response to these same questions.

In the program effort to provide information to growers and others, numerous educational activities were designed and conducted.

These included: (1) cotton insect short course, (2) 13 producer meetings in Hidalgo, Willacy and Cameron counties, (3) 76 daily cotton insect reports on radio and television programs, (4) 16 weekly cotton insect newsletters, (5) 6 news releases, (6) 3 television programs, (7) a cotton clinic, and (8) encouragement by letter to attend the U.S. Department of Agriculture field day where much of the research on short season cotton, discussed in the South Texas program, is located (Frisbie, et.al., 1973 b).

In summary, the 1973 program was successful in gaining the confidence and support of participating producers. This is due to reliability of scouting reports, closer contact with producers and the educational activities. Growers have realized that larger pest populations should be tolerated before control treatment is initiated and many producers are now basing insecticide applications on field survey data (Frisbie, et.al., 1973 b).

PROGRAM FEASIBILITY AND EXPANSION

The Rio Grande Valley program became viable in 1973. It is beginning to have a slight impact on quantity of insecticide applied and a significant one on yields and producer net returns.

The program has attained credibility in the region and can be expected to be more influential in the pest management decisions of producers in 1974. A limitation (stemming from funding limitation) of the program is the small percent of total cotton acres included in the program. This means non-participating producers surround participating producers and, hence, significantly affect the pest control program of participants. Insecticide drift destroys beneficial populations. Non-participant neighbors not following a diapause program create boll weevil problems for neighboring producers. This is a limitation to the effectiveness of the program even with very cooperative program participants. Their options are reduced to insecticide for insect control.

Therefore, exceptionally good arguments exist for expansion of the program to include more acres and not have them dispersed among non-participants. With most growers in an area cooperating, there are excellent opportunities to reduce insecticide use dramatically without incurring any yield loss.

A possible useful adjustment in this program would be to integrate the South Texas program strategy into the program. This is being done to some extent since the county extension entomologist is closely connected with the short season cotton research and represents a direct contact to producers. The program would be improved by greatly emphasizing overall production recommendations (including fertilization, timing of irrigation, harvest recommendations and insect control). This region has an excellent opportunity to direct an integrated pest management program toward bringing about some basic cotton production adjustments.

II. BLACKLANDS PROGRAMS

This program is located in Hill and Ellis counties between Waco and Dallas. It is an agriculturally diversified area with the major crops grain sorghum, cotton and small grains (Frisbie, et.al., 1972 b). However, the area is primarily rolling prairie with hardwood timber and brush found in the western part.

About 175,000 acres of cotton is produced in Hill and Ellis counties with an average yield of nearly 300 pounds of lint per acre but reaching 500 to 600 pounds for some producers (Frisbie, et.al., 1972 b). The cotton is produced without irrigation.

Typically, farmers practice early season control spraying for thrips, aphids and fleahoppers. The insect control strategy of the producers was a schedule of spraying every 10 days beginning with plant emergence and ending about June 10 (Frisbie, et.al., 1973 b).

The boll weevil is also evident in this area. However, due to the relatively low yields of cotton, late season applications for its control are, in farmers' opinion, economically questionable. In addition, late or mid-season insecticide applications often result in outbreak of bollworms and insecticide resistant tobacco budworms.

Due to the nature of insect problems confronting cotton production in the Blacklands, an integrated pest management program was needed. As in the Rio Grande Valley, recommendations on several phases of production should be included in such a program including improved varieties, early stalk destruction, insecticide application, crop rotation and planting dates (Frisbie, et.al., 1972 b).

PROGRAM CHARACTERISTICS

The objectives of the Blacklands program were to: (1) assess pest populations and use chemical insecticides only where damaging insect populations existed, (2) avoid indiscriminate destruction of beneficial insects with unnecessary insecticide applications, and (3) develop an integrated insect control program using cultural and chemical controls, thus preserving naturally occurring biological control organisms. All of these objectives would hopefully increase producer net returns (Frisbie, et.al., 1972 b). About one-half of the cost of the seven scouts employed in 1972 and 1973 for this program were paid by producers. The producers' share of scouting costs were collected by the Blackland Cotton and Grain Producers Association.

As for all of the Texas scout programs, late funding in 1972 delayed initiation of this program into the growing season. The scouts received intensive training in field insect identification, biology, damage recognition, and scouting techniques (Frisbie, et.al., 1972 b).

Participating grower's fields were scouted weekly. A report for each grower's field was sent to the grower and to the county extension entomologist. The county extension entomologist and grower worked together in making pest control decisions.

In 1972, the seven scouts covered 11,550 acres of cotton or 1,650 acres per scout. The program control area was a 5 x 7 mile area and essentially all the cotton in the area was included (Frisbie, et.al., 1972 b). This is an advantageous approach to instigating a regional integrated pest management program since it minimizes the influence of non-participant actions (compared to dispersion in the Rio Grande Valley program). There were 61 participating producers with 274 fields.

In 1973, the acreage scouted was reduced by 1,284 acres. The seven scouts covered 10,266 acres of cotton (1,467 acres per scout) for 59 producers on 208 fields. Three percent of the 1972 participating producers did not re-enter the 1973 program (Frisbie, et.al., 1973 b). There was more personal contact with individual producers in 1973. This is obviously the best method of educating the grower, in addition to producer meetings.

USERS AND LOCATION

This program is located in Hill and Ellis counties. Total acres of cotton produced in these counties is about 190,000 acres per year (Texas Crop Reporting Service). This indicates about five percent of all acres in the area were in the program.

There were 7,059 acres of cotton in Hill county and 4,491 acres in Ellis county in the program in 1972, as compared to 5,747 acres in Hill and 4,519 in Ellis during 1973 (Frisbie, et.al., 1972 b; 1973 b).

As in the Rio Grande Valley program, acres of cotton produced and size of farm for program cooperators is not readily available. However, to estimate yields and insecticide use of participants and non-participants in 1973, two samples of 22 growers (each sample representing similar managerial and production capabilities) were selected (Frisbie, 1974 c). The distribution of these growers by acres of cotton is presented in Table D-31.

Table D-31. Distribution of a sample of participating and non-participating cotton producers by acres of cotton produced, Blacklands, 1973[a]

Cotton acreage distribution	Number of producers	
	Participating	Non-participating
0 - 50	12	11
51 - 200	10	11
201 and greater	0	0

[a] Source (Frisbie, 1974 c).

These samples (for which the reliability regarding the distribution of cotton among the population is unknown) indicate a good balance between participants and non-participants. This could be expected since this program delineated a 5 x 7 mile area and includes most of the cotton in this area. Although this is an appropriate method of demonstrating and achieving an integrated pest management program, there is a problem of obtaining the "spinoff" to non-participants, particularly those who are situated several miles from the program. This suggests the need to expand the program to other areas in the region; this is not feasible with the current program budget.

ASSESSMENT -- 1972

The limitations indicated for the Rio Grande Valley also apply to an evaluation of the 1972 Blacklands program; i.e., a late start due to delayed program funding and the lack of a control group.

Biological effectiveness

For participating growers in 1972, the average lint yield was 385 pounds per acre. This is compared to an estimated 330 pounds of lint per acre by non-participating producers (Frisbie, 1972 a). This suggests a 55 pound of lint per acre yield increase in the control area where insect populations exceeded economic damaging levels an average of 2.6 times (Frisbie, 1972 a).

Although cooperation by participating farmers in making insecticide applications based on individual field insect reports from cotton scouts was good, the mild winter and spring of 1971-72 resulted in population pressure from boll weevil and pink bollworm. On most of the fields where mid-season insecticide applications for boll weevil were made, there were outbreaks of cotton bollworm and tobacco budworms

(Frisbie, et.al., 1972 b). In only these cases were bollworm-tobacco budworm insecticide applications made.

Costs and returns

Implementation: Implementation costs of this program do not include costs allocated to the state level which are discussed after the Frio County program. These costs, as reported in Table D-32, were incurred primarily by the Federal Cooperative Grant Funds and the Texas Agricultural Extension Service (Frisbie, 1974 a). Total implementation costs were an estimated $9,500 with $4,000 originating from Federal Cooperative Agreement Funds and $5,500 from Texas Agricultural Extension Service funds.

Table D-32. Estimated Implementation Costs of the Blacklands Scout program[a]

Item	Source of funds		
	Grant[b]	TAEX[c]	Total
	dollars		
Mapping	1,000	1,000	2,000
Grower contact	1,000	1,000	2,000
Recruitment	1,000	2,000	3,000
Scout training	1,000	1,500	2,500
Total	4,000	5,500	9,500

[a] Source (Frisbie, 1974 a).

[b] Cooperative funds from the U.S. Department of Agriculture

[c] Texas Agricultural Extension Service

Program costs: Costs of the 1972 Blackland program were incurred by the Federal Pest Management Grant funds, Texas Agricultural Extension Service and cooperating producers. The 1972 program costs, by source of funds, are presented in Table D-33 for the period May 17, 1972 to December 31, 1972.

Total 1972 program costs in the Blacklands was $18,055, not including implementation costs or costs allocated to the state level (reported after Frio County evaluation). Of this, 56 percent was paid by Federal Grant funds ($10,093), 19 percent by the Texas Agricultural Extension Service ($3,200) and 26 percent by cooperating producers ($4,762). This indicates that total program costs per acre of cotton in the program was $1.56.

Producer: Producers in this program treated for insects an average of 3.4 times per acre and applied 1.88 pounds of insecticide per application (Frisbie, 1972 a). The cost of materials and application was an average of $6.62 per acre. There was no control group in 1972, hence, direct comparisons cannot be made relative to insect control. However, there is an indicated 55 pounds of lint per acre increase for cooperators which would be associated with an increase in gross income.

Environmental implications

Expanding the average 6.39 pounds of insecticide applied per acre to the 11,550 acres in the program indicates that in the control area over 70,000 pounds of insecticide were introduced into the environ-

Table D-33. Blacklands program cost by source of funds, 1972[a]

Item	Unit	Cost per unit	No. of units	Total cost	Source of funds		
					Grant[b]	TAEX[c]	Producer
					----------- dollars ------------		
Salary							
County Extension entomologist	man	7,005	1	7,005	7,005	0	0
Scouts	man	1,112	7	7,784	3,892	0	3,892
Clerical	program	1,130	1	1,130	1,037	0	93
Travel							
County Extension entomologist	program	3,973	1	3,973	773	3,200	0
Scouts	program	1,145	1	1,145	640	0	505
Supplies, misc. and incidentials	program	1,018	1	1,018	746	0	272
Less implementation cost	program	-4,000	1	-4,000	-4,000	0	0
Total				18,055	10,093	3,200	4,762

[a] Source (Frisbie, 1973 a).

[b] Cooperative funds from U.S. Department of Agriculture

[c] Texas Agricultural Extension Service

ment. Without a control group, the quantity of insecticides that could have been expected without the program cannot be estimated. With cooperating producers accepting the concept of applying insect control based on population rather than a regular schedule, it is expected that the effectiveness of insecticide treatments is improved and a reduction in total number of treatments is likely.

As with all Texas programs, there is continuous safety and health monitoring. During the 1972 Blacklands program one scout showed a depression in cholinesterase levels, all others were within normal limits (Frisbie, et.al., 1972 b).

Participating growers evaluation

A questionnaire completed by participating growers indicated that 90 percent felt the program gave them reliable information on which to base their insecticide applications. A measure of the success of this program is in an expressed desire in non-control areas for cotton scouting (Frisbie, et.al., 1972 b). Of the 1972 participating growers, only 3 percent elected not to participate in the 1973 program (Frisbie, et.al., 1973 b).

Producer contact in 1972 was through educational meetings and individually. Meetings during the growing season to answer producers questions about the program were not well attended (Frisbie, et.al., 1972 b). Although educational meetings are useful, an increase in individual contact, use of regular insect report newsletters and use of news media is suggested for program improvement. This was planned for the 1973 program.

In summary, the 1972 Blacklands program gained producer confidence and was successful in convincing many producers to use insecticides based on pest population rather than a predetermined schedule. In 1972, only 45 percent of the participating growers indicated they used some form of boll weevil diapause control (Frisbie, et.al., 1972 b). This is an important part of an integrated pest management program, and was identified as an area of emphasis in 1973.

ASSESSMENT -- 1973

For the 1973 Blacklands program, emphasis was placed on evaluation. Of primary importance was the establishment of a control group.

Much care was exercised to make this control group as comparable as possible to the participating producers. For example, it was attempted to have producers in both groups who were using the same variety and irrigation practices and had the same farm management capabilities (Frisbie, et.al., 1973 b). Data were collected for 22 participating growers and 22 non-participating growers. These data provide the basis for much of the analysis.

Biological effectiveness

Excess rainfall occurred in 1973 but overall the insect pressure was relatively light (Frisbie, et.al., 1973 b). For most cotton acres, insecticide applications were not required for thrips. There was some damage from lygus bugs on cotton fields located next to grain sorghum. Boll weevil populations were extremely low in the program area as compared to 1972. In many fields, an early season application of insecticide was directed at overwintering boll weevils. There were no applications of insecticide for control of bollworms (Frisbie, et.al., 1973 b).

Using data from 22 participating and 22 non-participating growers, average lint yield in 1973 was 457 pounds and 410 pounds, respectively (Frisbie, et.al., 1973 b). The 47 pound (11 percent) increase in lint production per acre for participating producers, compared to non-participating producers, is a positive measure of program success.

The standard deviation was computed to estimate the variations of yield from the average lint yield per acre. The estimates, 79 for participating growers and 83 for non-participating growers, were not significantly different and therefore indicated that yield variations were about the same for both groups. Implications are that growers not in the program could switch to the program without sacrificing the stability of yield. These variation measures strengthen the argument that lint yields per acre increased under the program.

Costs and returns

Economics of the Blacklands program is considered from the cost of conducting the program and implications of the program on individual producer production practices and corresponding costs and returns.

Program costs: Expenditures for the 1973 Blacklands program, by type and source of funds, is presented in Table D-34. Total costs, not including costs allocated to state coordination, were $30,006 in 1973 (Frisbie, 1974 b). Of this the Federal Grant funds paid $20,941 (70 percent), $3,200 by the Texas Agricultural Extension Service (11 percent), and $5,865 by cooperating producers (19 percent). This means the cost per acre of cotton in the program was about $2.92, compared to $1.56 in 1973. The increased per acre cost in 1973 is explained by costs being incurred over a 12 month period and on less acres in the program.

Producer: To evaluate overall economic implications of participating growers, relative to non-participating growers, data from the two sample groups were used. Producers in the control sample were selected that had comparable managerial capabilities as the sample of participating growers. The data relative to producer inputs and yield were processed by applying an Enterprise Budget Generator computer program (Frisbie, et.al., 1973 b). The results from each group of producers is summarized in Table D-35.

The larger yield of participating growers resulted in gross revenue per acre being $21.20 more than for non-participating growers. The participating grower did incur more costs for harvest, due to a higher yield, and a larger total production cost than non-participating growers ($118.56 compared to $115.31). The difference in terms of net

Table D-34. Blacklands program cost by source of funds, 1973[a]

Item	Unit	Cost per unit	No. of units	Total cost	Source of funds		
					Grant[b]	TAEX[c]	Producer
				---------- dollars	----------	----------	----------
Salary							
County Extension entomologist	man	11,992	1	11,992	11,992	0	0
Scouts	man	1,331	7	9,317	4,309	0	5,008
Clerical	program	1,378	1	1,378	1,378	0	0
Travel							
County Extension entomologist	program	4,667	1	4,667	1,467	3,200	0
Scouts	program	1,405	1	1,405	924	0	481
Supplies, misc. and incidentals	program	1,247	1	1,247	871	0	376
Total				30,006	20,941	3,200	5,865

[a] Source (Frisbie, 1974 b).

[b] Cooperative funds from U.S. Department of Agriculture

[c] Texas Agricultural Extension Service

Table D-35. A comparison of expected per acre costs and returns for participating and non participating cotton producers in the Blacklands program, 1973[a]

Item	Unit	Price or cost per unit	Participating grower		Non-participating grower	
			Quantity	Value or cost	Quantity	Value or cost
Returns						
Lint	lb.	0.40	457	182.80	410	164.00
Seed	ton	80.00	.36	28.80	.33	26.40
Total				211.60		190.40
Variable costs						
Preharvest[b]	acre	N.A.	1	42.16	1	43.08
Harvest[c]	acre	N.A.	1	44.24	1	40.07
Fixed costs[d]	acre	N.A.	1	32.16	1	32.16
Total cost	acre	N.A.	1	118.56	1	115.31
Net returns	acre	N.A.	1	93.04	1	75.09

[a] Source (Frisbie, et.al.. 1973 b). Itemized enterprise budgets were developed using the Enterprise Budget Generator computer program. This analysis does not consider government farm programs.

[b] Most of the difference in participating and non-participating preharvest costs are due to a greater quantity of insecticide applied by non-participating growers.

[c] The difference in harvest cost for the two groups is explained by the yield difference.

[d] A fixed cash lease land charge of $20.00 per acre was charged.

revenue per acre was $17.95 more for participating growers ($93.04 compared to $75.09). These data indicate the Blacklands program has been successful in improving net returns for participating growers.

Environmental implications

Insecticide use of participating growers was slightly less than for non-participating growers, based on data from the two sample groups. Participating growers applied an average of 1.6 applications of insecticide per acre and .438 pounds per application; hence a total of 0.7 pounds of insecticide per acre was applied by participating growers. Non-participating growers applied 0.438 pounds of insecticide an average of 2.3 times for a total annual per acre application of 1.0 pound (Frisbie, et.al., 1973 b).

This is a reduction of 0.3 pounds of insecticide per acre or a 30 percent decrease that can be attributable to the Blacklands program. This implies that the program in 1973 was responsible for reducing quantity of insecticide used by over 3,000 pounds. Using the 168,000 acres of cotton in Hill and Ellis Counties, extrapolation of the data above imply that a program including all cotton in the counties would have reduced the total quantity of insecticides introduced into the environment from 168,000 pounds to 117,600 pounds. This, of course, applies only to 1973 which was a year of light insect pressure for this area. The effect of the program on insecticide use in a year of heavy insect pressure has not been quantified. However, with an area wide integrated pest management program that includes essentially all of the cotton, a result similar in relative magnitudes would be entirely possible.

A grower questionnaire, in which 31 of 39 producers responded, indicated that the program saved them one insecticide application (Frisbie, et.al., 1973 b). This response is somewhat substantiated by the insecticide use patterns of the two samples of growers reported above.

Participating growers evaluation

To obtain growers comments and reaction to the program, a questionnaire was used. Thirty-nine of 58 participating growers completed the questionnaire (Frisbie, et.al., 1973 b). This discussion is a summary of the completed questionnaires.

For the 1973 Blacklands scout program, 37 of the 39 growers indicated they felt the reports were reliable and delivered promptly while 38 felt the survey provided timely information to control infestations. This is an indication of grower confidence in the program.

Thirty-one producers indicated the program saved them one insecticide application. Twenty-four producers said they both contacted the county extension entomologist when they had a question and used the "Texas Suggestions for Controlling Cotton Insects" published by the Texas Agricultural Extension Service while fifteen producers did not. The 15 producers may have been contacted by the county extension entomologist due to an indicated insect problem (hence the producer did not initiate the contact) and in conjunction with the county extension entomologist decided on the appropriate insect control (in which case the publication would not have been used directly).

Emphasizing producer's attitude toward the program, 30 of 39 indicated that they would like to see the county extension entomologist made more responsible for helping them time their insect control measures. This could be interpreted to mean that producers want the county extension entomologist to be responsible for deciding what to do and when to do it relative to insect control. This would defeat much of the program's purpose, that of providing information to improve the decision making capability of the producer. Conversely, the grower may be indicating he needs the advice or technical assistance of an expert in evaluating insect situations. The final decision relative to the specific pest management practice adopted would remain with the producer.

Thirty-one said they planned to participate in the 1974 program. Of the six not planning to do so in 1974, three indicated they would not have cotton in the control area in 1974 and three would plant grain sorghum. These six producers, particularly the three planting grain sorghum, create an interesting question by their decision against producing cotton in the program area. The implication is that net returns per acre of cotton for these producers (even with the program) were no as large as an alternative crop would be.

Regarding program spinoff, 25 growers felt that their neighbors, not participating in the program, gained some benefit from it; seven did not see any spinoff benefit. Regarding full producer support of the program, 19 indicated they would be willing to support the entire scout program at the rate of $1.50 per acre while 18 were not. This suggests some reluctance of producers to pay more than the current $0.75 per acre for the program. There are three possible explanations for this no response. First, the benefits as the producer perceives them are not worth another $0.75 per acre; second, by answering yes to full support of the program the producer may feel there would be an incentive for other types of support to be withdrawn, thus leaving full support of the program with him; or third, the program was introduced as a three year program where costs would be $0.75 per acre and producers felt program leaders should adhere to this basic obligation.

Lastly, the producers were asked if they would be interested in a grain sorghum scouting program to compliment the cotton program? Twenty-seven responded they would and 12 responded they would not (Frisbie, et.al., 1973 b). The majority response of yes indicates that grain sorghum is important in the overall management of cotton costs. Insecticide drift from treated grain sorghum often destroys beneficial insects in adjacent cotton, and thus, produce bollworm outbreaks. Also, the grain sorghum serves as a reservoir for beneficial insects that move into cotton. An integrated pest management program in an area should address the insect control from an overall production basis, including production of all crops in the area.

The above information is based on questionnaires completed by producers. An important information gap concerns the attitude of non-respondants. It would be useful to sample the non-respondants for their response to these same questions.

In the program effort to provide information to growers and others, numerous educational activities were designed and conducted.

These include: (1) a weekly cotton insect report sent to program cooperators, County Extension Agents, Extension Entomologist and the news media (local newspapers had a weekly column on the current insect situation), (2) short courses on cotton pest management were presented to producers, (3) educational meetings were held with Farm Bureau groups, Young Farmer Chapters, Gin Cooperatives, 7-steps Cotton Committees and small communities, (4) the insect situation was reported over the radio weekly, (5) a field day was conducted, (6) insect control demonstrations were conducted and (7) there were numerous personal meetings with area cotton producers (Frisbie, et.al., 1973 b).

In summary, the 1973 program did achieve producer confidence and there is evidence that participating producers apply insecticides based on pest populations rather than on a predetermined schedule. This closely follows the East Texas Program discussed earlier and can be considered as the extension of that program to a general area. Through educational meetings and direct producer contact, farmers increased their net returns in 1973 by more closely using an integrated pest management program that includes cultural, chemical and biological controls (Frisbie, et.al., 1973 b).

PROGRAM FEASIBILITY AND EXPANSION

Due to no control group in 1972 and a late start from late funding, the strong emphasis of an evaluation is on the 1973 program data. In the Blacklands, 1973 was a year of relatively light insect infestations. Therefore, this is a limitation in that program effectiveness in a year of relatively light insect infestations is somewhat uncertain.

Nevertheless, the concept of integrated pest management as practiced by the Blacklands program is sound and effective. Therefore, because of producer acceptance of insecticide applications based on insect infestations (as reported by cotton scouts) and because producers indicated awareness of the interrelationships between cultural practices and insect problems (as expressed in producers interest in a grain sorghum scout program), this program can be classified as viable and successful in influencing producers approach toward pest management.

The program area is 5 x 7 miles in size and includes most of the cotton acreage. The inclusion of all or nearly all cotton producers is the correct approach for instigating a successful regional integrated pest management program. The program has demonstrated success in increasing producer net returns, increasing lint yield and decreasing insecticide use.

However, an intensive program in a relatively small area can be expected to have limited spinoff effect. Therefore, with funding, other intensive programs on an area basis in the Blacklands will be needed to attain an expedient adjustment by regional producers to integrated pest management strategies. It is important that any additional programs in the region be on a total area basis similar to the Blacklands program. With total area programs dispersed in the area, the spinoff to non-program areas are expected to be accelerated.

Another desirable aspect of program expansion is to give greater emphasis to overall production needs and recommendations, for example, inclusion of grain sorghum in the program and recommendations to cooperators relative to pest control over the entire production system including crop rotation and other cultural practices.

A major limitation to program expansion is obviously financial support. It would be difficult to simply shift the existing program to another control area. This type of action would probably be interpreted by present participating producers as a sign that the program was not successful from the supporting agencies viewpoint, and, hence they may not attempt to continue the program. The producers would also not understand why governmental support was shifted from a successful program to begin another program in another area that may or may not be successful. These type problems are difficult and frustrating when dealing with limited funds and the need to maximize benefits from these funds.

To conclude the discussion of this program, it is essential to emphasize the importance of a strong producer organization and an enthusiastic, hard working county extension entomologist or county extension agent. Viewing integrated pest management programs from a Texas standpoint, these factors appear to be necessary conditions for a viable, successful program.

III. TRANS-PECOS PROGRAM

Cotton is the most important crop in the Trans-Pecos region which is comprised of Reeves and Pecos Counties (Frisbie, et.al., 1972 b). The cotton bollworm is the primary cotton insect pest and its influence is aggravated by early insecticide applications and applications of excessive nitrogen and irrigation water late in the season. Control of early season insects is seldom justified. Further, early initiation of bollworm control with insecticide (based on numbers and not potential damage) often forces a season-long insecticidal program that may include 12 to 26 applications (Frisbie, et.al., 1972 b). This enhances the likelihood of development of insecticide resistant insect strains as well as introducing unnecessarily large quantities of insecticide into the environment.

Yields from fields with very large numbers of insecticide applications are frequently 1/4 to 1/2 bale less than fields treated only when bollworm population and potential damage justified such control. In addition to a lower yield on fields receiving excessive insecticidal applications, surrounding forage crops with grazing livestock are subjected to drift and residue hazards (Frisbie, et.al., 1972 b).

In the Reeves and Pecos Counties, there are about 175,000 acres of cultivated land with around 35,000 acres of cotton produced by some 450 farmers. All cropland is irrigated. The arid climate of the area provides an opportunity for more control over many of the factors that must be considered in an integrated pest management program (Frisbie, et.al, 1972 b).

PROGRAM CHARACTERISTICS

The objective of the Trans-Pecos IPM program was to achieve cotton insect pest control based on sound ecological principles which integrate chemical, biological and cultural methods into a practical control program (Frisbie, et.al., 1972 b). Personnel for this program include primarily the county extension entomologist with assistance for producer educational activities by the county agricultural extension agent. A crew of cotton scouts was not used in 1972 to periodically survey cotton, only the county extension entomologist was so engaged. There were, however, commercial scouts that cooperated with the program in their work.

This program is based on the Pecos program discussed earlier. The Trans-Pecos program is the extension of the integrated pest management Pecos program to area producers.

The program objective is to have insecticide use for insect control based on actual field infestations and potential damage. This, of course, requires periodic scouting of cotton fields. Insect control decisions are made after considering the amount of fruit loss the cotton plant can tolerate at different stages of growth, expected duration of pest infestation, number of beneficial insect and spider populations present and probable effect of an insecticidal application on future insect populations (Frisbie, et.al., 1972 b). The program also includes certain agronomic practices including an early maturing crop, use of only sufficient fertilizer and irrigation water to produce a satisfactory crop and a diversified cropping system (Frisbie, et.al., 1972 b).

The Trans-Pecos program is based on a research program that began in 1968 and has received considerable publicity, both through the Trans-Pecos program and traditional public media. In this program the basic responsibility of the county extension entomologist is to provide subject matter information designed to strengthen entomology programs in the area. Programs and information were designed to better implement planning, execution and evaluation of insect control efforts as they relate to overall agricultural production (Frisbie, et.al., 1972 b).

The Trans-Pecos program was initiated on May 11, 1972 with the county extension entomologist making producer contacts in May and June. Fields to be scouted or monitored by the county extension entomologist were selected with assistance from producers and county extension agents. Data collection began on June 19 and continued to September 20. In 1972, the county extension entomologist scouted 1,000 acres of cotton (Frisbie, et.al., 1972 b).

In 1973, an additional county extension entomologist was employed. Also, nine cotton scouts were hired. With a supervised scouting program in 1973, cotton acres in the program were increased to 8,600 including 134 fields and 28 cooperating producers (Frisbie, et.al., 1973 b).

The Trans-Pecos Cotton Association assisted in organizing this program and collected $2.00 per acre from participating producers in

1973. This covered the total costs of the scouts salary and travel.

USERS AND LOCATION

The Trans-Pecos program is located in Reeves and Pecos Counties in West Texas. Out of about 35,000 acres of cotton, 1,000 acres were in the program in 1972 and 8,600 in 1973 (Frisbie, et.al., 1972 b; 1973 b).

As in all Texas scout programs, acres of cotton produced and size of farm for program cooperators is not readily available. However, to estimate yields and insecticide use of participants and non-participants in 1973, two samples of 14 growers (each sample representing similar managerial and production capabilities) were selected (Frisbie, 1974 c). The distribution of these growers, by acres of cotton, is presented in Table D-36.

These samples (for which the reliability regarding the distribution of cotton acres among the population is unknown) indicates a reasonable balance between participants and non-participants. In 1973, about 25 percent of the cotton acres in the region were participating in the Trans-Pecos program. This degree of participation is needed to achieve a regional integrated pest management program (although this particular program is quite effective on a single cotton field) and obtain rapid spinoff to non-participating farmers. With an educational and information emphasis, rapid adoption of the Trans-Pecos program throughout the region can be expected.

Table D-36. Distribution of a sample of participating and non-participating cotton producers by a[illegible] of cotton produced, Trans-Pecos. 1973[a]

Cotton acreage distribution	Number of producers	
	Participating	Non-participating
0 - 50	2	0
51 - 200	4	6
201 and greater	8	8

[a] Source (Frisbie, 1974 c).

ASSESSMENT -- 1972

The limitations indicated for the Rio Grande Valley also apply to an evaluation of the 1972 Trans-Pecos program, particularly the absence of a control group.

Biological effectiveness

For participating growers in 1972, the average lint yield was 750 pounds per acre (Frisbie, 1972 a). This is compared to an average for Pecos and Reeves counties of 715 pounds per acre (Texas Crop Reporting Service). In a very general interpretation, this suggests a 35 pound of lint per acre yield increase for participating producers.

With the program, insect control costs for participating growers were reduced an estimated $200,000 in this area even with an abnormally high pink bollworm population. Insect populations exceeded economically damaging levels an average of 8 times (Frisbie, 1972 a). The 1972 program was designed to obtain grower confidence and arrange for supervised scouting in 1973.

Costs and returns

Implementation: Implementation costs of this program do not include costs allocated to the state level which are discussed after the Frio County Program. The implementation costs, as reported in Table D-37, were incurred primarily by the Federal Cooperative Grant funds and the Texas Agricultural Extension Service (Frisbie, 1974 a). Implementation costs were an estimated $1,800 with $800 Federal Cooperative Agreement funds and $1,000 Texas Agricultural Extension Service funds.

Program costs: Cost of the 1972 Trans-Pecos program were incurred by Federal Pest Management Grant funds and the Texas Agricultural Extension Service. The 1972 cost, by source of funds, is presented in Table D-38 and is for the period May 17, 1972 to December 31, 1972.

Total 1972 operation costs in the Trans-Pecos were $15,679, not including implementation costs or costs allocated to the state level (reported after Frio County evaluation). Of this, 57 percent was paid from Federal Grant funds ($8,929) and 43 percent by the Texas Agricultural Extension Service ($6,750). This indicates that total program

Table D-37. Estimated implementation costs of the Trans-Pecos Scout Program[a]

Item	Source of funds		
	Grant[b]	TAEX[c]	Total
	dollars		
Mapping	300	0	300
Grower contact	500	1,000	1,500
Recruitment	d	d	d
Scout training	d	d	d
Total	800	1,000	1,800

[a] Source (Frisbie, 1974 a).

[b] Cooperative funds from the U.S. Department of Agriculture

[c] Texas Agricultural Extension Service

[d] Supervised scouting was not a part of the 1972 program.

Table D-38. Trans-Pecos Program cost by source of funds, 1972[a]

Item	Unit	Cost per unit	No. units	Total cost	Source of funds Grant[b]	 TAEX[c]
		dollars		----------	dollars	----------
Salary						
County Extension entomologist	man	5,750	1	5,750	5,750	0
Clerical	program	992	1	992	992	0
Travel						
County Extension entomologist	program	9,408	1	9,408	2,658	6,750
Supplies, misc. and incidentials	program	329	1	329	329	0
Less implementation cost	program	-800	1	-800	-800	0
Total				15,679	8,929	6,750

[a] Source (Frisbie, 1972 a).

[b] Cooperative funds from U. S. Department of Agriculture.

[c] Texas Agricultural Extension Service.

costs per acre of cotton in the program was $15.68. This cost figure is very misleading since much of the county extension entomologist effort was directed toward education and providing information to all producers in the area.

Producer: Producers in the program treated for insects an average of 10.9 times per acre and applied 1.04 pounds of insecticide per application. The cost of materials and application averaged $39.94 per acre (Frisbie, 1972 a). There was no control group in 1972, hence, no direct comparisons can be made relative to insect control.

Based on the yield of 750 pounds of lint per acre, producer-incurred insect control costs were 5 cents per pound of lint produced. For some non-participating producers insect control costs have been estimated as high as 36 cents per pound of lint produced (Frisbie, et.al., 1972 b). It is estimated that with a Pest-Management Supervisor offering technical assistance to producers in the area, cotton insect control costs were reduced by $200,000 in 1972 (Frisbie, et.al., 1972 b).

Environmental implications

Expanding the average 17.58 pounds of insecticide applied per acre to the 1,000 acres in the program indicates that in 1972, participating producers introduced 17,580 pounds of insecticide into the environment. Without a control group, the quantity of insecticides that could have been expected without the program cannot be estimated.

A shifting to more sophisticated pest management practices by producers is occurring. Over 50 percent of area producers have adopted scouting as a technique of pest management and some are modifying their agronomic practices (Frisbie, et.al., 1972 b). This would be expected to have a favorable effect on quantity of insecticides used.

Participating growers evaluation

Since there was no supervised scouting in 1972, only a few producers were in the program. The county extension entomologist directed a large part of his effort to educational and informational activities directed to all producers in the area. Through this program, farmers were influenced to be more cautious in application of insecticides. A complete analysis is made for 1973 when there was supervised scouting.

Relative to education and providing information, the county extension entomologist provided training and technical guidance to commercial insect scouts, scout supervisors and interested producers by conducting field demonstrations (Frisbie, et.al., 1972 b). There were also workshops held throughout the season for producers and local commercial scouts, mass media releases and weekly newsletters distributed to 200 producers and cotton industry personnel.

In summary, the 1972 Trans-Pecos program was relatively small in number of participating cotton acres, yet emphasized education and provided information area wide. There was considerable interaction with commercial cotton scouts, hence, wider dispersion of this integrated pest management program.

In 1972, without a control group, a meaningful evaluation is not possible. However, based on the Pecos program discussed earlier, there is an opportunity to further reduce insecticide use by participating growers. At the Pecos Agricultural Research Station, insecticide applications have been reduced to essentially zero, yet were over 16 on participating growers' cotton acreage. Of course, an overnight shift cannot be expected and the 1972 data indicated more emphasis is needed on providing overall production recommendations, including variety, fertilizer, irrigation, and crop rotation patterns.

ASSESSMENT -- 1973

For the 1973 program, there were several important changes including (1) initiation of a supervised scouting program, (2) furnishing cooperative producers with adequate information to logically evaluate field situations, (3) hiring an additional county extension entomologist and (4) including a control group for program evaluation purposes (Frisbie, et.al., 1973 b). The control group, which included 14 participating and 14 non-participating producers, was selected to have comparable managerial ability and productive capability.

Biological effectiveness

A long, cold spring in the Trans-Pecos delayed planting in 1973, hence, the first bollworm generation inflicted little damage (Frisbie, et.al., 1973 b). Typically, over fertilization and excessive irrigation and rainfall produces a lush attractive cotton plant and results in some economic damage from the second generation of bollworm. A steady decline of beneficials occurred from July to early August, thus insecticide treatments were initiated (Frisbie, et.al., 1973 b). The fall (September, October and November) was favorable for cotton production and allowed the late planted cotton to reach maturity.

Using data from 14 participating growers and 14 non-participating growers, average lint yield in 1973 was 751 pounds and 708 pounds, respectively (Frisbie, et.al., 1973 b). This represents a 43 pound (6 percent) yield increase for participating growers and indicates that an increase in output is associated with the Trans-Pecos program.

To test the variability in yield, an estimate of standard deviation was computed for yields of participators and non-participators. The variation in yield was found to be greater with the program than without the program. The standard deviation was 87 and 122 for non-participators and participators, respectively. The increased variation in expected yields could partially explain the lack of rapid adoption by area farmers.

Costs and returns

Economics of the Trans-Pecos program is considered from the cost of conducting the program and implications of the program on individual producer production practices and associated costs and returns. *Program costs*. Expenditures for the 1973 Trans-Pecos program, by type and source of funds, is presented in Table D-39. Total costs, not

Table D-39. Trans-Pecos program cost by source of funds, 1973[a]

Item	Unit	Cost per unit	No. of units	Total cost	Source of funds		
					Grant[b]	TAEX[c]	Producer
				------------	dollars	----------	
Salary							
County Extension entomologist	program	8,280	2	16,560	13,310	3,250	0
Scouts	man	1,062	9	9,558	0	0	9,558
Clerical	program	2,395	1	2,395	1,539	0	856
Travel							
County Extension entomologist	program	12,028	1	12,028	5,278	6,750	0
Scouts	program	2,078	1	2,078	0	0	2,078
Supplies, misc. and incidentials	program	2,211	1	2,211	1,148	0	1,063
Total				44,830	21,275	10,000	13,555

[a] Source (Frisbie, 1974 b).

[b] Cooperative funds from U. S. Department of Agriculture.

[c] Texas Agricultural Extension Service.

including costs allocated to state coordination, were $44,830 in 1973 (Frisbie, 1974 b). Of this, Federal Grant funds paid $21,275 (47 percent), $10,000 by the Texas Agricultural Extension Service (22 percent), and $13,555 by producers (30 percent). This means the cost per acre of cotton in the program was about $5.21 in 1973 with $1.58 paid by the producers; i.e., governmental costs were about $3.63 per acre. This is a substantial reduction in per acre program costs from 1972 but the per acre cost of this program remained higher than the other cotton insect management programs in Texas for 1973. As in the other programs, this cost does not include program costs allocated to the state level, and a part of the program effort is directed area wide, not to just participating producers.

Producer: To evaluate overall economic implications of participating growers, relative to non-participating growers, data from the two sample groups were used. Producers in the control sample were selected that had managerial capabilities comparable to those of participating growers. The data relative to producer inputs and yield were processed by applying an Enterprise Budget Generator computer program (Frisbie, et al., 1973 b). The results from each group of producers is summarized in Table D-40.

The larger yield of participating growers resulted in gross revenue per acre being $22.73 more than for non-participating producers. Production costs for the participating growers were slightly less than non-participating growers due to use of less insecticide. These per

Table D-40. A comparison of expected per acre costs and returns for participating cotton producers in the Trans Pecos program, 1973[a]

			Participating grower		Non-participating growers	
Item	Unit	Price or cost per unit	Quantity	Value or cost	Quantity	Value or cost
Returns						
Lint	lb.	.45	751	338.13	708	318.60
Seed	ton	80.00	.6	48.00	.56	44.80
Total				386.13		363.40
Variable costs						
Preharvest[b]	acre	N.A.	1	136.73	1	149.24
Harvest[c]	acre	N.A.	1	70.79	1	66.83
Fixed cost[d]	acre	N.A.	1	64.18	1	63.99
Total cost	acre	N.A.	1	271.70	1	280.06
Net returns	acre	N.A.	1	114.43	1	83.84

[a] Source (Frisbie, et.al., 1972 b). Itemized enterprise budgets were developed using the Enterprise Budget Generator computer program. This analysis does not consider government farm programs.

[b] Most of the difference in participating and non-participating preharvest costs are due to a greater quantity of insecticide applied by non-participating growers.

[c] The difference in harvest costs for the two groups is explained by the yield difference.

[d] A fixed cash lease land charge of $35.00 per acre was charged.

acre cost and return estimates include for participating growers, a $2.00 scouting charge.

Participating producers had an estimated net revenue of $114.43 per acre and non-participating $83.84. This represents a $30.59 per acre increase in net returns for participating growers or an increase of 36 percent. These data indicate the Trans-Pecos program has been successful in improving net returns for participating growers.

Environmental implications

Quantity of insecticides use by participating growers was not appreciably different from non-participating growers, based on data from the two sample groups. Participating growers applied an average of 6.1 applications of insecticide and total of 10.4 pounds of insecticide per acre. Non-participating producers sprayed an average of 10.4 times and applied 10.7 pounds of insecticide (Frisbie, et.al., 1973 b).

Participants used the same overall quantity of insecticides as non-participants because the former used toxaphene at rates of .75 to 1.5 pounds per acre whereas the latter used lower rates of organo-phosphate materials. The lower number of insecticide applications for the participating producers is an important trend. This means less fuel use due to reduced trips across the field and therefore reduced production costs.

The environmental impact of substituting larger quantities of toxaphene for relatively less organo-phosphates has not been quantified. From a quantity of insecticide use standpoint, the program has not reduced the amount entering the environment. However, the program does show a greater product (cotton lint) per pound of insecticide used.

A grower questionnaire (12 of 15 producers responding) indicated that the program saved them at least one insecticide application (Frisbie, et.al., 1973 b). The reduction in insecticide applications is environmentally promising. However, the Pecos program, of which the Trans-Pecos program is an extension, indicates substantial improvement is possible and needed in reducing insecticide use. This will occur only as producers are closely advised on all production activities; i.e., variety, cultural, fertilization, irrigation, etc. Also, this analysis is based just on 1973 which is not sufficient for definite conclusions.

Participating growers evaluation

To obtain grower comments and reaction to the program, a questionnaire was used. Fifteen of 29 participating growers completed the questionnaire (Frisbie, et.al., 1973 b). This discussion is a summary of the completed questionnaires.

For the 1973 Trans-Pecos scout program, 14 of 15 growers indicated they felt the reports were reliable and delivered promptly, while 13 felt the survey provided timely information to control infestations. This is an indication of grower confidence in the program.

Twelve producers indicated the program saved them at least one insecticide application. Thirteen producers said they contacted the county extension entomologist when they had a question but only 10 of the 15 used the "Texas Suggestions for Controlling Cotton Insects" published by the Texas Agricultural Extension Service.

Relative to producer attitude, 12 of 15 indicated they would like to see the county extension entomologist more responsible in helping them time their insect control measures. Thirteen of the 15 responding producers planned to participate in the 1974 program (Frisbie, et.al., 1973 b).

Regarding program spinoff, two producers felt that their neighbors not participating in the program gained some benefit from it; thirteen did not see any spinoff benefit (Frisbie, et.al., 1973 b). This is a rather surprising reaction and suggests that efforts to influence cotton producers area wide may be weak. Conversely, it could indicate the requirement for a well qualified entomologist to make key insect control decisions on a field by field basis. In order to bring about a continuing integrated pest management program in the area, the Trans-Pecos program will need to be expanded or the use of well trained commercial scouts must be increased significantly.

The need for close coordination and contact with cotton scouts and county extension entomologist became clear late in the 1973 growing season when scouts returned to school and the two county extension entomologists had to inspect the 8,600 program acres. Requests, particularly during this period, were registered for fewer acres allocated per scout (Frisbie, et.al., 1973 b).

In the program effort to provide information to growers and others, numerous educational activities were designed and conducted. These include: (1) 6 news releases, (2) 11 circular letters, (3) a production conference, (4) a field day, (5) contact with non-cooperating producers, and (6) meetings with organizations and groups (Frisbie, et. al., 1973 b). Although this is a demanding schedule, some increase in emphasis on education and providing information is suggested. The use of radio and television would reach most producers in the area. Also, a weekly column in the area newspapers on pest management and current status would help orient non-participating producers to thinking in terms of integrated pest management strategies.

In summary, the 1973 program did not have the benefit of a supervised scout program in 1972, hence, experience in running such a program had to be gained in 1973. For 1973, the data indicate some success is being achieved in demonstrating usefulness of integrated pest management to participating growers in the form of increased output, increased net returns and reduced number of insecticide applications.

PROGRAM FEASIBILITY AND EXPANSION

Since the Trans-Pecos program had no control group in 1972, funding was late delaying initiation,and there was no supervised scout program, most of the program evaluation is based on 1973 results.

First, participants had a larger cotton yield, higher net returns, and make about one-third less insecticide applications. This indicates program accomplishment and progress in influencing cotton production. The increased net return for participants of $30.59 per acre implies producer benefits of $263,074 in 1973. This, of course, far exceeds the $31,275 government costs of the program. This demonstrates an improved production technique for which there is significant incentive for the producer to pay all the costs.

Regarding the pay-off to society, other than increased efficiency of production and more lint, there was a reduction in insecticide applications of from 10.4 to 6.0. This is significant and indicates a favorable environmental trend. However, due to participants using larger quantities per application of toxaphene compared to organo-phosphates, the quantity of insecticides used was basically unchanged. The environmental implication of this substitution is not quantified. This gives an inconclusive environmental result.

Reviewing the program and results thereof, this is a viable program that is showing favorable results. This program uses much of the Pecos program technique as a basis. Based on this, the potential in terms of reducing insecticide use is very significant. The 1973 program only began what is hoped to be a trend and did not approach the potential. This can be explained by the need for cooperation by the producer in all phases of overall production. This type transformation is practically an institutional change and can be expected to occur only gradually.

Regarding program spinoff, there is some evidence of limited program influence on non-participants. This is not conclusive but suggests the need to emphasize education and provide information area wide. In all fairness, since about 25 percent of the area cotton acreage is in the program, the influence on non-producers may be subtle and already reflected somewhat in county statistics. This is, of course, most difficult to measure.

Given that this is a most promising program with perhaps somewhat limited success relative to its potential, concern turns to expansion or new emphasis. Extension at the current level with regard to acres appears appropriate with more emphasis on area wide educational and information service. In addition, the need to relate to and influence the total production system of the participating growers is most important. This program hinges on short season cotton with appropriate fertilizer and irrigation water use; the assistance of a soil scientist in making recommendations to producers is required.

IV. FRIO COUNTY PROGRAM

Frio County, 30 miles southwest of San Antonio, has many characteristics that make it an ideal location for testing the feasibility of an area wide pest management program. There is a strong farm organization, all major Texas cotton pests occur, there is a history of heavy insecticide use, and the small cotton acreage is relatively isolated from cotton in surrounding counties (Frisbie, et.al., 1972 b).

Principal sources of agricultural income in this area include peanuts, grain sorghum, melons, corn, vegetables, cotton and livestock (Frisbie, et.al., 1972 b). County cotton acreage is around 1,500 acres.

PROGRAM CHARACTERISTICS

The objective of the Frio County program was to modify pest management practices based on sound production, economic and biological principles (Frisbie, et.al., 1972 b). For this county, a key to the insect problem lies with boll weevil control. Therefore, for improved pest management an effective diapause boll weevil control program is essential to eliminate the need for boll weevil control during the growing season.

Efforts to develop improved pest management strategies in Frio County began before the 1972 scout program. Much of the earlier effort, which is still continuing, was research. Therefore, participants in the program included the Frio County Cotton Growers Association, South Texas Agricultural Experiment Station and ARS, USDA (Frisbie, et.al., 1972 b). Of course, the research effort in the county influenced the program, but this report attempts to separate the research side from the analysis.

This means the Frio County program rests primarily with the county extension entomologist. The county extension entomologist was responsible for scouting (there were some commercial scouts also), presenting educational material, developing and implementing an effective diapause boll weevil control program and assisting growers with insect control (Frisbie, et.al., 1972 b). In 1973, more emphasis was placed on increasing producer awareness of economic injury levels and limiting insecticide use to only those cases justified by insect populations (Frisbie, et.al., 1973 b).

There was a diapause program in 1971. However, delayed harvest due to late season rain and a mild winter significantly reduced its effectiveness. The Frio County program began after a meeting of the Cotton Growers Association on April 13. However, the county extension entomologist was unable to begin work until June 11. Since most cotton was planted in March, early season scouting was not possible under the program (Frisbie, et.al., 1972 b). This delay affected the total 1972 program.

The diapause control phase of the Frio County program was initiated around August 5; fields were placed on a 5-day spray schedule until defoliation, when the schedule was extended to 10 day intervals until stalk destruction (Frisbie, et.al., 1972 b). Although farmer cooperation was good in the diapause program, in many fields after stalk destruction regrowth occurred and several farmers were reluctant to take steps to keep all growth down. For diapause control until stalk destruction, all farmers in the county were asked to sign a contract giving the Frio County Cotton Growers Association permission to treat their fields. This was needed to get an effective area-wide program (Frisbie, et.al., 1972 b).

In 1972, approximately 1,700 acres of cotton were produced on 48 fields. The county extension entomologist scouted all cotton in the county. Several fields were also scouted by the U.S.D.A., the Texas Agricultural Experiment Station and professional consultant scouts. Therefore, scouting by the county extension entomologist in 1972 was primarily for survey purposes (Frisbie, et.al., 1972 b).

As indicated earlier, the 1973 Frio County program increased emphasis on attempting to influence in-season insect control as well as improving the effectiveness of the diapause control program. There were 1,312 acres of cotton grown in Frio County in 1973, but evidence of boll weevil infestation originating from outside of the county resulted in an expansion of the program to 1,422 acres in order to include fields bordering Frio County (Frisbie, et.al., 1972 b).

With total county inclusion in the program and support by the Cotton Growers Association, this program represents an opportunity to test the feasibility of an area-wide integrated pest management program. The 1972 and 1973 programs, however, emphasized insect control with only limited consideration of desirable varieties and optimum fertilizer and irrigation strategies.

USERS AND LOCATION

Frio County is in South Texas located 30 miles southwest of San Antonio. All county cotton acres in 1972 (1,700) and 1973 (1,312 plus bodering fields of 110 acres) were included in the program. This involved 30 producers in 1972 with 48 fields and 20 producers in 1973 with 28 fields (Frisbie, et.al., 1972 b; 1973 b).

Since all cotton acres in the county were included in the program, all producers were included. With the total population of producers involved, there is little reason to be concerned with the distribution of users by acres of cotton produced.

Program leadership, and hence an organizational program user, was provided by the Frio County Cotton Growers Association. Program direction involving producers was made during meetings of this organization (Frisbie, et.al., 1973 b).

ASSESSMENT -- 1972

In 1972, the Frio County program was initiated in an area where a strong producer group and signficiant research effort already existed. The evaluation of this program was made most difficult because the research was on farms in the IPM program. The amount and type of effect of the research program on producers' pest management strategies are not quantified. Furthermore, within the growing season, the insect management program in 1972 was utilized primarily for survey purposes rather than to provide information and advise producers. This was altered in 1973. Program emphasis in 1972, relative to influencing pest management tactics, was directed toward improving the effectiveness of the diapause control program. The limitations and emphasis are important in evaluating the program; e.g., no control group (all producers included), late start, ongoing research program, no scout team or stated program objective.

Biological effectiveness

Acres of cotton in Frio County ranged from 1,100 in 1971 to 3,100 in 1969. There is more irrigated cotton than dryland. A shift in the proportion of irrigated and dryland occurs between years, and therefore a comparison of average yields among years has limited meaning, but is still useful to the analysis.

Average cotton yield based on harvested acres was in the range of 530 to 560 pounds from 1968 through 1971, excluding 1962 when it was 297 pounds (Texas Crop Reporting Service). In 1972, the average yield was 625 pounds of lint per acre (Texas Crop Reporting Service).

This yield increase in 1972 may be attributed partly to the 1971 diapause control program, research in the area, the Frio County program and growing conditions.

Another possible explanation is quite low cotton acreage in 1971 from which pests evolved. This is not likely the situation, however, because boll weevils began building fairly rapidly in June. Most producers began treating for boll weevils the first of July. Those that did not treat for boll weevils sustained consistently heavy square and boll damage. Furthermore, the early season pesticide treatments probably assisted in the initiation of the outbreak of cotton bollworms and tobacco budworms primarily by destroying beneficials (Frisbie, et.al., 1972 b). Some difficulty was encountered in the insecticidal control of the tobacco budworm.

The 1972 Frio County program had as one of its purposes to gather information useful in following years relative to an integrated pest management program. The necessity of reducing boll weevil population so that early season control can be avoided was evident due to need for beneficials for holding Heliothis population in check (Frisbie, et.al., 1972 b).

There was an increase in per acre yields of cotton (to 882 pounds on irrigated and 350 on dryland) in 1972 (Texas Crop Reporting Service). This yield increase is an indication of biological effectiveness. Furthermore, although insect damage was found, insect populations exceeded economic damaging numbers only twice (Frisbie, 1972 a). The implication is that the 1971 diapause program, and perhaps relatively low 1971 cotton acreage was somewhat effective and producers were premature in some cases in initiating early insect control measures in 1972.

A correct adjustment for the 1973 program included improving effectiveness of the diapause control program and discouraging producers from applying insecticides unnecessarily.

Costs and returns

Implementation: Implementation costs of the program do not include costs allocated to the state level (which are discussed after this program) or which were research oriented. The implementation costs reported in Table D-41 were incurred primarily by the Federal Cooperative Grant funds and the Texas Agricultural Extension Service (Frisbie, 1974 a). Implementation costs were an estimated $1,400 of which $1,100 were Federal Cooperative Agreement funds and $300 Texas Agricultural Extension Service funds.

Program costs: Costs of the 1972 Frio County program were incurred by Federal Pest Management Grant funds and the Texas Agricultural Extension Service. The 1972 costs, by source of funds, is presented in Table D-42 and 43 for the period May 17, 1972 to December 31, 1972.

The total 1972 operations cost in the Frio County program was $12,297 and did not include implementation costs or costs allocated to the state level. Of this, 57 percent was paid from Federal Grant funds ($7,047) and 43 percent by the Texas Agricultural Extension Service. The proportionate distribution of program costs between the Federal Grant funds and the Texas Agricultural Extension Service is identical to that for the Trans-Pecos program in 1972.

Table D-41. Estimated implementation costs of the Frio County program[a]

Item	Source of Funds		
	Grant[b]	TAEX[c]	Total
	----------dollars	------------------	
Mapping	600	0	600
Grower Contact	500	300	800
Recruitment	d	d	d
Scout training	d	d	d
Total	1,100	300	1,400

[a] Source (Frisbie, 1974 a).
[b] Cooperative funds from the U.S. Department of Agriculture.
[c] Texas Agricultural Extension Service.
[d] Supervised scouting was not a part of this program.

Table D-42. Frio County program cost by source of funds, 1972[a]

Item	Unit	Cost per Unit	No. of Units	Total Cost	Source of funds	
					Grant[b]	TAEX[c]
Salary				-------- dollars	--------	--------
County Extension Entomologist	man	6,560	1	6,550	6,560	0
Clerical	program	464	1	464	464	0
Travel						
County Extension Entomologist	program	6,255	1	6,255	1,005	5,250
Supplies, Misc. and incidentials	program	118	1	118	118	0
Less implementation costs	program	-1,100	1	-1,100	-1,100	0
Total				12,297	7,047	5,250

[a] Source (Frisbie, 1973 a).
[b] Cooperative funds from U.S. Department of Agriculture.
[c] Texas Agricultural Extension Service.

On a per acre of cotton basis, the costs of the program in 1972 were $7.06, about one-half the Trans-Pecos program costs but considerably larger than the Rio Grande Valley program or Blacklands program.

Producer: Producers in Frio County treated for insects an average of 13 times per acre and applied 1.84 pounds of insecticide per application. Average per acre costs of insect control to producers, not including any Frio County program costs, were $37.50 (Frisbie, 1972 a). This included some diapause control by producers.

Overall, insect control in 1972 would not be much different from previous years. This means any economic advantage to the producer would be realized through the increased 1972 yield.

Environmental implications

Expanding the 23.92 pounds of insecticide applied per acre to the 1,700 acres of cotton in Frio County indicates that in 1972, 40,664 pounds of insecticide were introduced into the environment. This is not expected to be appreciably different from previous years, hence, program effect in 1972 relative to the environment does not show any significant improvement.

This again emphasizes the need for an effective diapause-control program to eliminate need (1) for in-season boll weevil control and (2) to encourage producers to not treat unnecessarily. These were goals for 1973.

Producer contact

Education and providing information were important responsibilities of the 1972 Frio County program. This was accomplished by radio, newspaper, letters, telephone, personnel and Cotton Growers Association meetings (Frisbie, et.al., 1972 b).

Although the 1972 program had little affect on in-season insecticide use, it coordinated the diapause control program (which is reflected in the 1973 evaluation) and introduced producers to the potential role of the county extension entomologist.

Summarizing for 1972, the program was basically designed for data collection and not to influence farmers. In fact, this scout program for 1972, even more than others in Texas, could aporopriately be classified as implementation rather than operations. Since this was the case, program evaluation in terms of reduced pesticide use, reduced pest population or increased yield could not be expected to indicate significant desirable shifts. This means the Frio County evaluation will necessarily be heavily based on 1973 results which is a single year and therefore has serious limitations.

ASSESSMENT - 1973

In 1973 the objectives of the program included (1) making producers more aware of economic injury levels, (2) reducing insecticide treatments by carefully monitoring economic thresholds, and (3) carrying out a county reproductive-diapause program (Frisbie, et.al., 1973 b). In 1973, over 1,300 acres of cotton were grown in Frio County. These acres along with one bordering farm accounted for 20 producers and 28 fields (Frisbie, et.al., 1973 b). Among the producers, considerable variation exists in production practices. Cotton is grown both dryland and under irrigation, harvesting is done with pickers and strippers, and insecticides are applied heavily to some acres while little to no insecticides are applied to others (Frisbie, et.al., 1973 b).

Biological effectiveness

In 1973, the second generation boll weevils caused economically damaging levels to be reached in almost every field (Frisbie, et. al., 1973 b). The diapause program seemed to effectively control first generation weevils, while other pests were not considered to exceed specified damage levels. Bollworm and tobacco budworm populations were very light especially when compared to the 1972 levels (Frisbie, et.al., 1973 b).

A record year for rainfall was experienced in 1973. Fields remained wet for long periods with excessive plant damage due to local flooding. The late crop was conducive to attack by insect population An average of 3.4 in-season applications and 4.9 boll weevil diapause applications were made per acre (Frisbie, et.al., 1973 b).

A control group, including six participants and six non-participants, were chosen with similar managerial ability and productive capacity. For these growers the average yield was 687 and 681 pounds per acre for participants and non-participants, respectively. Only a slight yield increase was present for participants, but environmental conditions in 1973 possibly prevented an accurate measurement of programs effectiveness. There is no difference in yield that has any significance.

Although a yield increase is not evident, based on the two sample groups, the average lint yield for Frio County was about 130 to 150 pounds above recent years. This follows 1972 results also. Since the entire county is in the program, this is some indication that a part of the overall yield increase can be attributed to the IPM program.

Relative to insect populations, the diapause-control program, even though not as effective as desired, is delaying outbreak of boll weevil populations, hence, preserving beneficials for a longer period into the growing season. This is due to less in-season insecticide applications in Frio County compared to recent non-program years.

Costs and returns

Economics of the Frio County program is considered from the costs of conducting the program and implications of the program on individual producer production practices and associated costs and returns. *Program costs*: The expenditures for the 1973 Frio County program are presented by type and source of funds in Table D-43. Total costs, not including costs allocated to state coordination, were $20,303 in 1973 (Frisbie, 1974 b). Of this total, $15,053 (74 percent) was paid by

Table D-43. Frio County program costs by source of funds, 1973[a]

Item	Unit	Costs per Unit	No. of Unit	Total Costs	Source of Funds	
					Grant[b]	TAEX[c]
				------- dollars	---------	
Salary						
County Extension Entomologists	program	12,248	1	12,248	12,248	0
Clerical	program	906	1	906	906	0
Travel						
County Extension Entomologists	program	6,631	1	6,631	1,381	5,250
Supplies, Misc. and incidentials	program	518	1	518	518	0
Total				20,303	15,053	5,250

[a] Source (Frisbie, 1974 b).
[b] Cooperative funds from U.S. Department of Agriculture.
[c] Texas Agricultural Extension Service .

Federal Grand Funds and $5,250 (36 percent) by the Texas Agricultural Extension Service.

The 1973 program included 1,477 acres which means the the average cost of the program per acre was approximately $14.27. This cost was paid from the government grant and Texas Agricultural Extension Service funds only; no producer funds were expended. As in all of the programs, these figures do not include program costs allocated to the state level.

Producer: To evaluate the economic implications of the programs, a sample of six participating growers and six non-participating growers was used. These 12 growers were chosen such that similar productive capacity, including management ability, existed. The data relative to producer inputs and yields were processed by an Enterprise Budget Generator computer program ([illegible], et al., 1977 a). The results from each of the producer groups are shown in Table D-44.

The yield of 887 pounds and 853 pounds of lint per acre for participants and non-participants, respectively was not significantly different. Preharvest costs were slightly higher for participants due to a greater amount of insecticides applied. However, this was due principally to local flooding which resulted in several additional insecticide treatments. Harvest costs were approximately equal.

Initially, it appears as if the program had no success in lowering insecticide costs and total preharvest costs. The difference

Table D-44. A comparison of expected per acre costs and returns for participating and non-participating cotton producers in the Frio County program, 1973[a].

Item	Unit	Price or costs per Unit	Participating growers Quantity	Participating growers Value or Costs	Non-participating growers Quantity	Non-participating growers Value or Costs
Returns						
Lint	lb.	.40	687.5	275.00	681.4	272.56
Seed	ton	90.00	.55	49.50	.55	49.50
Total				324.50		322.06
Variable Costs	acre	NA				
Preharvest	acre	NA	1	110.68	1	104.18
Harvest	acre	NA	1	69.32	1	68.75
Fixed Costs	acre	NA	1	72.24	1	72.24
Total Costs	acre	NA	1	252.24	1	245.17
Net Returns	acre	NA	1	72.26	1	76.89

[a] Source (Frisbie, et.al., 1973 b). Itemized enterprise budgets were developed using the Enterprise Budget Generator computer program. This analysis does not consider government farm programs.

in preharvest costs is due primarily to insecticide cost which was $46.17 and $43.29 for participants and non-participants, respectively. However, this total for program participants includes $16.82 for the fall diapause program which is actually directed at the 1974 crop (Frisbie, et.al., 1973 b). Therefore, the costs of in-season insecticide application was $29.35 for participants as compared to $43.29 for nonparticipants (Frisbie, et.al., 1973 b). Applying this to the net returns, the participants in the program would have realized a $12.09 gain if the boll weevil diapause program had not been initiated (Frisbie, et.al., 1973 b).

Environmental Implications

Based on the sample groups, the program participants were able to reduce the total insecticide applications when the fall boll weevil diapause program is considered separately as it should be. Table D-46 shows the average number of treatments along with average pounds per acre of insecticides for the two groups. Comparison of in-season treatments show that under the IPM program, growers successfully reduced treatments. Non-participants treated an average of 13.1 times while participants treated only 8.0 times, or a reduction of five total treatments. Participating growers applied an average of 14.1 pounds of insecticide for in-season control, while non-participating growers applied an average of 19.4 pounds per acre. This represents a 5.3 pound or a 30 percent reduction of in-season insecticide used due to the program. Once again, the lower number of insecticide applications reduces fuel usage as the total trips over the field is reduced. This results in

Table D-45. A comparison of insecticide applications of participants and non-participants in Frio County, 1973[a]

	Average Number of applications	Average number of pounds of insecticide per acre
Participant[b]		
In-season	8.0	14.1
Diapause	4.1	7.0
Non-Participant[b]		
In season	13.1	18.9
Diapause	4.1	7.0

[a] Source (Frisbie, et.al., 1973 b).

[b] Based on sample group including 6 participating growers and 6 non participating growers.

lower production costs as well as more preservation of beneficials for biological in-season control.

Education

To promote the program, the county extension entomologist used several education methods including: (1) producer meetings, (2) newsletters, (3) individual letters and insect reports, and (4) personal grower contacts (Frisbie, et.al., 1973 b). Meetings were held before and during the season to report on program progress, discuss goals of the program, and to enlist more grower support. Weekly newsletters were mailed to inform producers of the county wide insect problems along with any other information considered beneficial to the producer. After each field inspection, insect reports were sent and personal contact was made if the insect situation was critical. Personal contacts proved to be the most successful, but time constraints prevented extensive use of this method unless essential (Frisbie, et.al., 1973 b). Due to the success of personal assistance, it is possible that the addition of another county entomologist could increase the interest and support of the program.

PROGRAM FEASIBILITY AND EXPANSION

In 1973, all cotton growers in Frio County plus one adjoining farm were included in the program. To test the feasibility of the study a sample of six county producers and six producers (not in the program) from the adjoining Edward Plateau region were chosen.

First, program participants experienced yields consistent with yields of non-participants. No significant difference could be detected in the average yields of the two groups. However, the participating growers suffered some losses due to locally adverse weather forcing a delay of harvest in some fields. In-season insecticide applications were down almost 40 percent with pound per acre of insecticides reduced by 30 percent. Total pounds of insecticides were increased by the participant group as an area wide fall boll weevil reproductive diapause program was one of the objectives for the 1973 program. The late rainfall required a more intense diapause control program than would normally be expected. Although diapause control was applied in 1973, it is an investment directed toward controlling the early season boll weevils the following year. Such a program must be considered viable if it is able to successfully reduce early weevils the next year, consequently reducing in-season insecticide applications. Consistent yield with less in-season insecticides, in a year of severe weather disturbances, indicates that the Frio County program is successful.

Regarding society's benefit, there was a reduction in total pounds of in-season chemicals applied by the participating growers, but for the total year an increase in quantity of insecticide used. The reproductive-diapause program was a relatively new program and if success is realized comparable to other areas of the state, even less insecticides could be introduced annually. However, an evaluation of the diapause program is necessary before conclusive results can be given for environmental impact.

In 1973, a few area producers demonstrated support of the IPM program, but most producers showed little concern for the effort (Frisbie, et.al., 1973 b). Only one entomologist was employed full-time to promote the program area-wide without assistance of a supervised scout program. Due to the size and nature of the program, this represents an over-commitment for one man. Many area producers hired a professional cotton scout independent of the program (Frisbie, 1974 b).

The program in Frio County is affected by the adjoining counties. Little or no diapause control is practiced in these counties, thus early season insect problems in Frio County often originate outside the county. As a result, producer interest in the area has been a severe limitation to success of this program. Emphasis of this program needs to be promoting grower interest area wide. The program does show promise for improving production systems, but cooperation of growers is essential for area acceptance.

For program continuation, there appears to be real opportunities to affect pest management practices in Frio County. To obtain this end, the program needs to be (1) closely coordinated with the commercial or the professional cotton scouts in the area, (2) integrate overall production considerations of variety, fertilization, irrigation and crop rotation and (3) generate more producer interest using the Frio County Cotton Growers Association.

V. TOTAL TEXAS COTTON INSECT MANAGEMENT PROGRAM COST

In the preceeding program evaluations of cotton insect management, four different cotton production areas were selected, all with important cotton pest problems, to test the feasibility of an area-wide integrated pest management program. To improve efficiency and obtain some continuity between programs, a statewide coordinator and project leader operates the program (Frisbie, et.al., 1972 b). It is the statewide project leader's responsibility to provide leadership, guidance, and consultation while avoiding duplication in the four Texas scout programs. A Texas cotton pest management program steering committee composed of members of the Texas Department of Agriculture, U.S. Department of Agriculture, Texas Agricultural Experiment Station and Texas Agricultural Extension Service provide program suggestions and comments (Frisbie, et.al., 1972 b).

IMPLEMENTATION

There are costs incurred for statewide coordination that do not apply to a particular cotton insect management program but to all of them. This section considers implementation, 1972 and 1973 costs incurred for state program coordination, and the summation of costs across all levels for a state total.

Implementation-state coordination

Program implementation costs at the state level are presented, by source of funds, in Table D-46. Data in Table D-46 indicates

Table D-46. Estimated implementation costs of the Texas cotton insect management program incurred at the state level[a]

Item	Source of funds		
	Grant[b]	TAEX[c]	Total
	----------------	dollars	----------------
Mapping	0	1,500	1,500
Recruitment	0	2,000	2,000
Developing forms	0	2,000	2,000
Developing data processing	1,500	0	1,500
Area delineation	0	2,000	2,000
Program development	0	7,000	7,000
Total	1,500[d]	14,500	16,000[e]

[a] Source (Frisbie, 1974 a).

[b] Cooperative funds from the U.S. Department of Agriculture.

[c] Texas Agricultural Extension Service.

[d] Does not include U.S. Department of Agriculture costs associated with initiating and obtaining program funding.

[e] Does not include any research components underlying the scout techniques or recommended pest management strategies.

that $16,000 was expended on program implementation at the state coordination level. This includes $1,500 from Federal Pest Management Grant funds and $14,500 from the Texas Agricultural Extension Service. An estimate is not included for federal costs to initiate and obtain funds for this program because this was a multi-state effort, and such an estimate would be inappropriate for the total United States program.

Implementation-state total

Implementation costs for the total Texas cotton insect management program is a summation of each of the four area programs and state coordination costs as given in Table D-47. Total implementation costs were an estimated $41,700 of which 31 percent ($12,900) was paid from Federal Pest Management Grant funds and 69 percent ($28,800) from Texas Agricultural Extension Service funds.

An implementation cost of $41,700 was incurred to initiate a program that included Federal Management Grant funds of $70,717 for 1972 (May 17 through December 31). However, this is a three year program. These implementation costs indicate that to carry out area-wide integrated pest management programs requires a substantial financial commitment even before the program begins.

OPERATION

1972 Operation-state coordination

In coordinating the four cotton insect management programs in Texas, costs of the state coordinator are the primary factor. However, Table D-47. Estimated implementation costs of the Texas cotton insect management program -- Texas total[a]

Classification	Source of funds Grant	 TAEX	 Total
	---------- dollar	----------	----------
Mapping	3,400	4,500	7,900
Grower contact	4,000	3,800	7,800
Recruitment	2,000	6,000	8,000
Scout training	2,000	3,500	5,500
Developing forms	0	2,000	2,000
Developing data processing	1,500	0	1,500
Area delineation	0	2,000	2,000
Program development	0	7,000	7,000
Total	12,900	28,800	41,700

[a] Source (Frisbie, 1974 a). Detailed implementation costs for each regional program are presented in the evaluation of that region.

revising programs, improving efficiency and developing desirable evaluation techniques includes some costs for professionals not directly associated with the program. The state coordination costs are presented in Table D-48.

The largest costs were for scientists. This was a new program and, as expected, considerable resources were needed to develop, revise and plan for an efficient program. This process of course continues in a viable dynamic program.

State coordination costs in 1972 were an estimated $28,088 with $14,518 (52 percent) paid by Federal Pest Management Grant funds, $5,170 (18 percent) paid by the Texas Agricultural Extension Service and $4,200 (15 percent) paid each by the Texas Agricultural Experiment Station and U.S. Department of Agriculture.

1972 Operation-state total

The lateness of funding from Federal Pest Management Grant funds influenced the effectiveness of the 1972 program. Therefore, much of the 1972 effort was directed toward educating and providing information, gathering data and gaining producer confidence. Due to these circumstances, it would not be unrealistic to consider the 1972 program operation costs presented in Table D-49 as implementation costs.

Total program operation costs in 1972 were $109,505. This does not include Federal Pest Management funds of $12,900 that were allocated to implementation costs. Therefore, of the $109,505, Federal

Table D-48. State coordination cost of the Texas insect management program by source of funds, 1972[a]

Item	Unit	Cost per unit	No. of units	Total cost	Source of funds			
					Grant[b]	TAEX[c]	TAES[d]	U.S.D.A.[e]
Salary				------------- dollars -------------				
State coordinator	man	9,475	1	9,475	9,475	0	0	0
Clerical	month	390	3	1,170	0	1,170	0	0
Travel	program	2,200	1	2,200	2,200	0	0	0
Supplies, misc. and incidentials	program	343	1	343	343	0	0	0
Computer services	program	4,000	1	4,000	4,000	0	0	0
Overhead								
Entomologists	SMY[f]	40,000	.2	8,000	0	0	4,000	4,000
Other Extension specialist	SMY[f]	40,000	.1	4,000	0	4,000	0	0
Advisory scientist	SMY[f]	40,000	.01	400	0	0	200	200
Less implementation cost	program			-1,500	-1,500	0	0	0
Total				28,088	14,518	5,170	4,200	4,200

[a] Source (Frisbie, 1973 a; 1974 a).

[b] Cooperative funds from U.S. Department of Agriculture. This does not include U.S.D.A. costs to manage the grant funds.

[c] Texas Agricultural Extension Service.

[d] Texas Agricultural Experiment Station.

[e] U.S. Department of Agriculture.

[f] Scientific man year.

Table D-49. Texas cotton insect management program cost by source of funds, 1972[a]

Item	Unit	Cost per unit	No. of units	Total cost	Source of funds				
					Grant[b]	TAEX[c]	TAES[d]	U.S.D.A.[e]	Producer
				----------------------	----------	dollars	----------	----------	----------
Salary									
Entension entomologists	program	36,790	1	36,790	36,790	0	0	0	0
Scouts	program	38,219	1	24,786	12,393	1,140	0	0	11,253
Clerical	program	4,776	1	4,776	3,513	1,170	0	0	93
Travel									
Extension entomologists	program	30,350	1	30,350	7,725	22,625	0	0	0
Scouts	program	6,175	1	6,175	4,022	0	0	0	2,153
Supplies, misc., and incidentials	program	3,128	1	3,128	2,275	90	0	0	763
Computer services	program	4,000	1	4,000	4,000	0	0	0	0
Overhead									
Entomologists	SMY[f]	40,000	.2	8,000	0	0	4,000	4,000	0
Other Extension specialists	SMY[f]	40,000	.1	4,000	0	4,000	0	0	0
Advisory scientists	SMY[f]	40,000	.01	400	0	0	200	200	0
Less implementation costs	program	-12,900	1	-12,900	-12,900	0	0	0	0
Total				109,505	57,818	29.025	4,200	4,200	14,262

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[a] Source (Frisbie, 1973 a; 1974 a). The costs do not include a U.S. Department of Agriculture estimate for managing the Pest Management Grant funds.

[b] Cooperative funds from U.S. Department of Agriculture.

[c] Texas Agricultural Extension Service.

[d] Texas Agricultural Experiment Station.

[e] U.S. Department of Agriculture.

[f] Scientific man years.

Pest Management funds paid $57,818 (53 percent), the Texas Agricultural Extension Service $29,025 (27 percent), the Texas Agricultural Experiment Station and U.S. Department of Agriculture $4.200 (4 percent) each and producers $14,262 (13 percent). Salary and travel accounted for the vast majority of the funds.

The 1972 program included 34,080 acres of cotton. This indicates the cost per acre of cotton in the program was $3.21. Implementation costs are not included in this estimate and the program did not begin operating until nearly June of 1972.

1973 Operation-state coordination

With program initiation in 1972 and several months of experience, 1973 efforts were directed to incorporating improvements into areas of the program with identified weaknesses and developing a complete procedure for program evaluation.

Cost for state coordination of the Texas cotton insect management program is presented in Table D-50. Total coordination costs for Texas in 1973 were an estimated $33,963 where 57 percent was incurred by Federal Pest Management Grant funds, 19 percent by the Texas Agricultural Extension Service and 12 percent each by the Texas Agricultural Experiment Station and U.S. Department of Agriculture.

Expenditures in 1973 for state coordination were $5,874 more than 1972 (20 percent increase) but the 1972 program covered only seven months as compared to 12 months in 1973. In view of this, the 1973 increase is quite realistic.

Table D-50. State coordination cost of the Texas cotton insect management program by source of funds, 1972[a]

Item	Unit	Cost per unit	No. of units	Total cost	Source of funds			
					Grant[b]	TAEX[c]	TAES[d]	U.S.D.A.[e]
				dollars				
Salary								
State coordinator	man	15,091	1	15,091	15,091	0	0	0
Clerical	month	390	6	2,340	0	2,340	0	0
Travel	program	2,724	1	2,724	2,724	0	0	0
Supplies, misc and incidentials	program	643	1	643	643	0	0	0
Computer Services	program	764	1	764	764	0	0	0
Overhead								
Entomologists	SMY[f]	40,000	.2	8,000	0	0	4,000	4,000
Other Extension specialists	SMY[f]	40,000	.1	4.000	0	4,000	0	0
Advisory scientists	SMY[f]	40,000	.01	400	0	0	200	200
Total				33,962	19,222	6,340	4,200	4,200

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[a] Source (Frisbie, 1973 a; 1974 a).

[b] Cooperative funds from the U.S. Department of Agriculture.

[c] Texas Agricultural Extension Service.

[d] Texas Agricultural Experiment Station.

[e] United States Department of Agriculture.

[f] Scientific man year.

1973 Operation-state total

Program costs in 1973 were larger than in 1972 because of the extra months the 1973 program covered and increased emphasis of closer producer contact in 1973. Costs of the 1973 program, by source of funds, are presented in Table D-51.

Total costs for the Texas cotton insect management program in 1973 were an estimated $177,251 (an increase of $67,745 or 62 percent above 1972 costs). The major increases in financial support for 1973 were from Federal Pest Management Grant funds (nearly double) and producer funds (a 64 percent increase). Funds from the Texas Agricultural Extension Service increased 11 percent.

In 1973, 35,916 acres of cotton were included in the Texas insect management program. The cost per acre of cotton in the program was $4.94 or 50 percent higher than those of the 1972 program. This increase is explained by the need to more intensely scout each field (acre) and have closer producer contact. In addition, the cost on a per acre basis is somewhat misleading since the program in each area included educational and information services for the entire region.

Table D-51. Texas cotton insect management program cost by source of funds, 1973[a]

Item	Unit	Cost per unit	No. of units	Total cost	Source of funds				
					Grant[b]	TAEX[c]	TAES[d]	U.S.D.A.[e]	Producer
				----	----	---- dollars	----	----	----
Salary									
Entension entomologists	program	68,635	1	68,635	65,385	3,250	0	0	0
Scouts	program	37,646	1	37,646	19,421	0	0	0	18,225
Clerical	program	8,773	1	8,773	5,577	2,340	0	0	856
Travel									
Entension entomologists	program	35,123	1	35,123	12,498	22,625	0	0	0
Scouts	program	8,035	1	8,035	5,476	0	0	0	2,559
Supplies, misc. and incidentials	program	5,875	1	5,875	4,162	0	0	0	1,713
Computer services	program	764	1	764	764	0	0	0	0
Overhead									
Entomologists	SMY[f]	40,000	.2	8,000	0	0	4,000	4,000	0
Other Extension specialists	SMY[f]	40,000	.1	4,000	0	4,000	0	0	0
Advisory scientists	SMY[f]	40,000	.01	400	0	0	200	200	0
Total				177,251	113,283	32,215	4,200	4,200	23,353

[a] Source (Frisbie, 1973 a; 1974 a). The costs do not include an estimate for the U.S. Department of Agriculture for managing the pest management grant funds.

[b] Cooperative funds from the U.S. Department of Agriculture.

[c] Texas Agricultural Extension Service.

[d] Texas Agricultural Experiment Station.

[e] U. S. Department of Agriculture.

[f] Scientific man year.

OVERALL FEASIBILITY

There are basically three types of integrated pest management programs discussed for cotton production in Texas. These include the diapause boll weevil control programs, regional programs based on overall production practice strategies and the cotton insect management program. Although considerably interrelated, these major types of programs will be considered separately relative to feasibility and limitations to expansion.

I. DIAPAUSE BOLL WEEVIL CONTROL PROGRAMS

The Texas High Plains and Glasscock County programs are diapause boll weevil control programs. Each program was developed for the climatic and production characteristics of the region. Also of major importance, each program has strong producer support.

Considering cost effectiveness, the High Plains program has been estimated to be responsible for an additional $27 to $46 million increase in net returns to producers (Lacewell, et.al.). The cost of the program, including producer financial support, is slightly over $1 million on an average annual basis. This indicates the program benefits far exceed the costs. The Glasscock County program, assuming a very conservative no increase in yield, shows a reduction in production costs (increase in net returns) of $150,000 where the average annual program cost based on 1971, 1972 and 1973 was $19,000. The increase in producer net returns per dollar of program costs (7 to 1) are similar for these two diapause control programs and show a very favorable level of benefits relative to program costs.

Considering the effect of the programs on pesticide load, the reduction in pesticide use is from several applications to near zero for Glasscock County and for the Texas High Plains is estimated to be between 8 and 20 million pounds annually (Lacewell, et.al.). Again a measure that indicates these programs are associated with a substantial degree of success.

A last measure of program success involves cotton output. For Glasscock County, a conservative estimate of no yield change was made. For the High Plains, it is estimated that if the program were discontinued, cotton output would decline between 75,000 and 125,000 bales (Lacewell, et.al.).

Based on the above measures, the boll weevil diapause-control programs in Texas are viable. They are associated with far more benefits than they cost; they reduce the quantity of pesticides introduced into the environment and result in an increase in the quantity of cotton produced.

These are two individual cases and were based on intensive research before initiation of the program. In addition, a research component continues to be a part of the program with adjustments continually incorporated. Therefore, these kinds of results may or may not be obtained in other areas.

The objective of a diapause boll weevil control program is to delay or eliminate the need for in-season boll weevil control. Therefore, to be effective and practical, these programs must be carefully planned and conducted with particular attention given to the weevil's biology and behavior in a specific geographical area (Thomas). This means considerable research on what constitutes an effective program in an area is needed prior to program initiation. Therefore, a restriction to expansion of the program is the requirement for sound prior research on the weevil's biology and behavior in a specific geographical region. For diapause control programs, where results were poor, some reasons given are (1) improper timing of diapause applications, (2) delayed post-harvest stalk destruction, (3) inadequate in-season weevil control prior to initiating the diapause program and (4) poor grower participation (Thomas).

The points above indicate a second important restriction to program expansion, poor grower participation. Both of the programs considered here have strong grower participation. The Glasscock program began with 100 percent grower participation. After a few years (with very favorable results) the program was expanded into part of a neighboring county with less than 100 percent producer participation. The effect of the lack of producer support was quickly evidenced in lack of effectiveness for that area. Without clear evidence of total producer participation and support, a boll weevil diapause-control program will experience only limited success at best.

Although the Texas High Plains and Glasscock County programs were selected for discussion on feasibility of boll weevil diapause-control programs, most of the programs considered in this report include diapause-control for boll weevils as an integral part of the program. In these cases, it is difficult to single out and quantify the effectiveness of the diapause control-part of the program in any terms other than reduced in-season insecticide control. Rather, effectiveness of the total program needs to be evaluated. The boll weevil diapause-control part of these programs is, of course, subject to the restrictions and limitations to success discussed above. In fact, these limitations become even more important in the other programs since generally the producers cooperating with the program are dispersed among non-participating producers. This means the participating producer is vulnerable to the actions of the non-participating producer; i.e., even though the participating producer carries out an effective boll weevil diapause-control program, he may incur weevil infestations early in the season from a non-participating neighbor.

Several boll weevil diapause control programs have been successful in reducing or eliminating the need for in-season weevil control. These programs basically consist of stalk destruction after harvest and fairly heavy applications of insecticide in the fall to reduce the number of overwintering weevils. Boll weevil diapause-control programs can be expected to become more sophisticated in a rather short period of time.

Other control strategies which are showing real promise include manipulation of overwintering weevil habitat, host plant resistance, non-diapausing weevil strains and other genetic methods, pheromone trapping and population manipulation, parasite and/or pathogen utilization and sterile male techniques (Thomas). Although these look good, the appropriate combination of suppression methods has yet to be adequately designed, fully understood and effectively implemented (Thomas). This indicates these programs must be adjusting continually and a research component is important to improving effectiveness.

II. OVERALL MANAGEMENT PROGRAMS

The review of IPM programs in Texas indicate that opportunities exist for developing production management strategies to deal with cotton pest problems. Experimental programs have shown that carefully designed changes in management techniques can be effective as tools for pest management. This study has proposed three management systems in which pests have been adequately controlled below economic threshold levels. At the same time, costs of production have been effectively decreased while yields have been maintained or increased. The increased yields and reduced costs have increased the grower's net returns.

The three production management systems described above include a program designed for (1) East Texas, (2) South Texas, and (3) the Pecos Region of Texas. In the East Texas program, a fall diapause program was initiated to complement the selected treatment of in-season pests. This diapause program effectively postponed early season boll weevil treatments, thus allowing for increased natural regulation of pests. Pest populations were also carefully sampled and unnecessary applications avoided. In the South Texas program, short season (early maturing) determinate cotton cultivars were substituted for conventional non-determinate cotton cultivars. This technique was designed so that the cotton was actually set and approaching harvest before insect populations reached economically damaging levels. The management or production techniques such as early crop residue destruction along with proper water and nitrogen input prevented heavy concentrations of cotton pests. In the Pecos area, the traditional management practice was to spray by calendar date or at the first sighting of cotton pests. However, by delaying insecticide applications until predetermined economic thresholds were reached, natural regulation almost totally replaced regulation by chemical insecticide.

It should be pointed out that these programs are experimental production management methods. The techniques have been carefully integrated into the overall management strategy of small groups of growers or program participators. Each program was developed for the particular production characteristics of a region. Each program has been experimental on relatively small acreages with the need now to incorporate the program into area wide utilization.

The merit of each of the three programs must be evaluated by the potential that the program holds for a region's production. In each of the controlled experiments, yield has been maintained while the production costs have been significantly reduced. Scientists that have developed and studied each of these programs believe that area wide adoption of these programs would compound the benefits that would be estimated by a simple summation over area acres. The conservation of beneficial arthropods is essential to all programs and area-wide acceptance would eliminate much undesirable influence from non-participants' adjacent fields.

Each of these three programs have successfully demonstrated how the grower can benefit from carefully designed production management strategies. Producers benefit from increased yield, higher returns, reduced production costs, reduced machinery operations thus reduced fuel use, and increased profit levels.

In the East Texas program, yields were increased, production costs decreased, thus profits were increased. To complement these producer benefits, a smaller quantity of total insecticides were introduced into the environment. Two experimental regions were considered in the East Texas program. A yield increase of 80 and 60 pounds per acre were estimated for the Trinity and Brazos River areas. Production costs were reduced by $4.24 and $.78 per acre resulting in increases of $34.62 and $22.61 in net returns per acre in the Trinity and Brazos regions, respectively. If these estimates are expanded to the total acres in both regions, the Trinity region would realize over $3 million increase in net returns while the Brazos region would realize over $7 million increase in net returns. This results in a total area increase of over $10 million in producer net returns. From these estimates it is apparent that area producers could financially support a program with this potential (Casey, et.al.).

Analysis from the South Texas program indicates yield would not be significantly different under the IPM program. However, the cost of insecticide treatments was reduced, hence, total production costs declined with the IPM overall management strategy. The estimated reduction in per acre production costs under the new program were $14.70. This was in conjunction with a reduction in quantity of insecticide applied of 4.09 pounds per acre. Regional potential of the program was estimated to be an increase of $2.7 million in profits. Of ecological importance, area wide acceptance of the program could result in 753,000 less total pounds of insecticides being injected into the environment per year (Larson, et.al.).

The third experimental program was established in the Pecos region of Texas. Experimental growers eliminated most of insecticide costs associated with cotton production while maintaining yield levels. Participants under the program applied only one insecticide treatment in a five year period compared with an average of 10 to 12 applications per year by other area producers. From this it was estimated that area producers could save as much as a million dollars annually in insecticide costs. This reduction has tremendous potential in an area where cotton production was only marginally profitable (Pate, et.al.).

These three production management programs have been shown, on a limited scale, to effectively improve cotton production conditions in various areas of Texas. Each of the programs can potentially benefit the total area in which the control program was developed. However, the programs have not been rapidly adopted by many of the respective area producers.

There exists the need to gain area wide confidence of the cotton producers in the programs. Funding is needed to provide technical assistance and guidance to the growers. Programs initiated throughout the areas to increase the awareness of producers would aid in rapid acceptance of the programs. Lack of interest due to unfamiliarity has been a major restriction to many of these programs. The general acceptance of these management techniques could result in more stability of cotton production in these areas.

Each of the programs described were designed for specific areas. However, opportunities exist for similar programs in all cotton regions. These management systems provide the basic design for developing and establishing similar programs for specific production conditions.

III. INSECT MANAGEMENT PROGRAM

Since each of the cotton insect management programs in Texas is evaluated separately, this discussion considers only aggregate or accumulated values for the state. This evaluation is based on the 1973 program due to data limitations associated with 1972 and, hence, represents a significant improvement over any evaluations based on 1972 such as Womack's. Basing program feasibility on a single year is also subject to severe limitations due to erratic weather patterns, changes in insect infestations and adjustments in cultural practices and cropping patterns. Therefore, it is essential that 1974 program results be reviewed as quickly as possible and compared to 1973. Inclusion of 1974 would substantially improve the validity of program feasibility evaluations.

Scout health monitoring was extensive in the Texas Pest Management program. Scouts received pre-employment physical examinations and a medical history was obtained. Blood samples for cholinesterase activity determinations were drawn every two weeks. In addition urine samples to determine paranitrophenol levels were taken.

COST EFFECTIVENESS

An objective of the Texas cotton pest management program was to improve net returns for cotton producers. A measure of this increase is obtained by considering the difference in per acre net returns by region for the program participants and non-participants and expanding to regional acres in the program. Using this procedure, the increase in producer net returns on 35,916 program acres was $1,298,566 or $36.16 per acre. Total program cost in 1973 was an estimated $177,251, including $23,353 from producers. This means the increase in producer net returns per dollar of program cost was about $7.33. This indicates the Texas insect management program in 1973 was effective in increasing producer net returns.

This analysis is based and dependent on the data provided by the two samples of producers (participants and non-participants). The non-participants were carefully selected relative to managerial ability to be comparable to program participants. However, it is useful to compare program participants to the average of all producers in the region.

Table D-52 presents average per acre lint yield for the sample of program participants and non-participants as well as the regional average. For the Rio Grande region only irrigated cotton was included. These data indicate that the better managers in each region were included in the program and were selected for comparison to program participants. The regional average lint yield is less than the sample of non-participants' average yield, except for the Trans Pecos. It is difficult to compare program participants to the county average since both upland cotton varieties and long staple varieties are planted. The two samples were selected to account for similar varieties to give a more valid comparison.

Table D-52. Per acre cotton lint yield for a sample of insect management program participants and non-participants and for the total region, Texas 1973[a]

Region or program	Scout Program[a]		Region[b] average
	Participants	Non-participants	
	-------------------- pounds of lint @ acre ---------		
Rio Grande	504	403	370
Blacklands	457	410	325
Trans Pecos	751	708	728
Frio County	687	681	646

[a] Source (Frisbie, et.al., 1973 b).

[b] Source (Texas Crop Reporting Service).

Nevertheless, some cost and return comparisons were made between program participants and county averages. Again, variety difference and generally the willingness of the better managers in an area to cooperate with integrating new technology into their farming operations cause limitations in comparison.

To begin such a comparison, cost of production per pound of lint for the sample of program participants and non-participants were compared. Typically, this cost was about equal or lower for program participants (see Table D-53). For purposes of costs and return analysis, Table D-53. Cost per pound of lint produced for a sample of insect management program participants and non-participants, Texas 1973[a]

Region or Program	Participants	Non-participants
	------- dollars per pound of lint -----	
Rio Grande	0.4125	0.4915
Blacklands	0.2594	0.2812
Trans Pecos	0.3618	0.3956
Frio County	0.3672	0.3599

[a] Based on data from this report as modified from (Frisbie, et.al., 1973 b).

the cost of production per pound of lint for program participants was applied to the regional average yields. By holding prices constant and calculating cost of production for the per acre average yield in the region, the increase in net returns for program participants, above regional average yields, was $734,450 across all program acres in Texas. This amounts to an increase in net returns of $20.45 per acre over the 35,913 program acres or an increase in producer net returns of $4.14 per one dollar of program expenditure ($177,251). Once again the limitations associated with this comparison or analysis are emphasized.

Therefore, the Texas cotton insect management program is a viable program but the integration of alternate pest control strategies into the pest control system for the region have not been achieved to any great extent (U.S. Department of Agriculture, 1974 a).

With an implied long run goal of integrating integrated pest management techniques to a region, some clarification and limitations of the current scout program are needed. The participating producers in 1973 adopted to a large degree recommended pest management strategies. However, in many of the program areas, participants were dispersed among non-participants. There are two points to be made here; (1) this is useful in maximizing program spinoff, of which there is no formal measure in 1973, but (2) the actions of non-participants often nullify an integrated pest management strategy thus greatly reducing program effectiveness.

This is a dilemna in that program spinoff to surrounding producers and regional adoption is a goal, hence, the dispersion apparently is needed. However, the effectiveness of the program is reduced and benefits not as obvious to non-participants, hence, they do not have an incentive to shift pest management practices. It is likely that blocks of land where all cotton acreage is in the program and the block is large enough for an integrated pest management program to be effective would be more desirable to demonstrate the program. This approach is associated with problems such as selection of an area and at what point producers support the program 100 percent and a new block or area is selected for governmental support.

Regarding expansion of the cotton insect management program, there are two major limitations; (1) financial support and (2) qualified scientists for a major proliferation. However, without expansion or more extensive localized programs, the potential of many integrated pest management strategies will not be realized due to the unfavorable influence of non-participant's actions.

BIOLOGICAL AND ENVIRONMENTAL EFFECT

Some of the increase in cooperating producer net returns was due to a per acre increase in lint production. Expanding the yield increase to cotton acres in the program, by region, indicates the program was associated with an increase of lint output of 2,150,164 pounds or some 4,300 bales of cotton. This represents an increase of 60 pounds of lint per acre over all acres in the 1973 program. The range was from an increase of 6 pounds of lint per acre in the Frio County program to a 101 pound increase in the Rio Grande Valley program.

Using regional average yields rather than the sample of non-participants (Table D-52), the increase in cotton output for program participants over the 35,913 scout program acres was 3,318,900 pounds of cotton lint. This amounts to 6,637 bales of cotton or a 92 pound per acre increase. The per acre increase in yield for participants ranged from 23 pounds per acre to 134 pounds per acre. As suggested before, the managerial differences of program participants and the average over the region greatly reduces any usefulness of these types of comparisons. Regional average data were included so that the information developed from the samples of program participants and non-participants might be put in perspective and be more meaningful.

Relative to quantity of insecticide used, particpating producers used 33,696 pounds more than non-participating producers; i.e., about one pound per acre more insecticide was used by participants. Considering rates of use of insecticides, this is not a significant increase. Based on insecticide use per pound of lint, there is a reduction in insecticide use for participating producers. For example, on the 35,913 program acres, in the absence of this program, expected insecticide use would have been 13.54 pounds per bale of cotton compared to 12.62 pounds per bale of cotton with the program; i.e., a reduction in pounds of insecticide use per bale of cotton produced of 7 percent. The reduction in insecticide use per bale of cotton produced due to the program ranged from 3.9 percent in the Trans-Pecos to 37.2 percent in the Blacklands.

The increase in yield suggests participating producers are more effectively using insecticides with better timing of application. Further, participating growers in areas with boll weevil problems cooperated with a diapause control program which included insecticide applications. In some of these cases, in-season use of insecticide declined relative to non-participating producers, but by including the diapause control aspects showed a total increase. Any benefits of the 1973 diapause control will be experienced in 1974, hence, the need for more than one year in establishing program feasibility.

PROGRAM FEASIBILITY

Overall, the Texas cotton insect management program is fulfilling the stated objectives of increasing producer net returns and making producers aware of improved pest management techniques. It was not particularly effective in reducing quantity of insecticide used in 1973. However, it was very successful in improving efficiency of cotton production as measured by lint output per pound of insecticide used. Major adjustments in pest management will not be altered to any large degree in one year, but rather gradually over several years.

Even though the Texas program is associated with a significant degree of success, some adjustments are needed over a long run period. Specifically, there is a need to place greater emphasis on all production practices. Pest management can not be separated from cultural practices, variety, crop rotation, fertilization or irrigation practices. This means the role of the county extension entomologist would be expanded to that of a production specialist and may involve more than one scientist with each of them carefully coordinating with the others. This would suggest an increase in governmental support to initiate a truly integrated program. In all fairness; there is a tendence in this direction in the Texas scout program but the financial limitations and scouting obligations do not permit a concentrated effort.

IV. FEASIBILITY OF INTEGRATED PEST MANAGEMENT PROGRAMS

The feasibility and viability of the different programs in Texas have been well established. Although different programs and strategies have been identified and discussed, most strategies are incorporated into each integrated pest management program. The regional boll weevil diapause control programs are apparently quite effective in checking spread of the weevil and suppressing weevil populations. Cotton insect management programs are successfully increasing producer net returns and creating an awareness by producers of integrated pest management practices. The localized integrated pest management programs, such as the Pecos program, are proven strategies with the potential presented.

COMPONENTS OF A SUCCESSFUL PROGRAM

From this evaluation of the Texas integrated pest management programs, some keys to their degree of success in relating to producers can be identified. In most cases, a strong producer organization is essential for attaining a focal point and for implementation of a viable program. Without this type of support, a unified, coordinated program is most difficult.

Related to the producer groups or associations is individual producer support. Without support of the producers, which can be encouraged through a producer organization, an integrated pest management program cannot be expected to be effective. Lack of producer support was a factor in Texas programs that experienced only partial success.

To gain producer support requires that the logical scientist (for example, the county extension entomologist) be competent and have above average initiative. The enthusiasm and ability of this person(s) is very important to the degree of success attained by an integrated pest management program.

The above requirements for a successful program assume a sound, well developed integrated pest management program. An effective and efficient program will require a strong research component, either directly or indirectly, to develop optimum pest management strategies and new and innovative approaches in all phases of cotton production. It is necessary that these programs be directed to local or regional levels and reflect the climate and problems at that level. The rate of adoption of an integrated pest management program by regional producers relates to effect on their net returns, primarily, and then to effectiveness of dissemination of information relative to the program.

ROLE OF GOVERNMENTAL SUPPORT

These points are important in considering expansion of any program. In addition to the above points, consideration of program continuation or expansion requires analysis of the role of governmental support. A reason for initial government financial support is that these programs would not be initiated or fully supported by producers. Continued governmental support can be justified only if expected or potential benefits exceed governmental costs. The nature and distribution of benefits then need to be investigated. Benefits are expected in terms of improved efficiency of production (reduced costs per unit of output and increased producer profits) as well as implied environmental enhancement (reduction in quantity of pesticides used).

If the benefits do not exceed costs then the program should be abandoned. However, if the converse is true, as with the Texas programs, decisions are complicated. If most benefits accrue to prodcuers and social benefits (not usually quantified) do not exceed governmental costs, continued governmental support is questionable.

Alternatively, if there are appreciable producer benefits (more than program costs) and social benefits exceed program costs, governmental support can be justified. However, benefits to producers are adequate to justify their fully supporting the program. The question then is, to what degree and how fast should the government release its obligation to producers? This is the point that has been reached with some Texas programs. Without the governmental financial support, it is likely producers would not continue the program on some acres. This is probably due to (1) the short life of the program and producers' uncertainty about benefits they would derive and (2) the small percent of total producers currently in the program. It would not be appropriate to discontinue proven programs on this basis and as confidence improves producers would be expected to gradually assume more of the costs of programs.

A last factor that needs to be considered is the dynamic nature of integrated pest management programs. Producers would likely attempt to minimize program costs and use strategies of the program as they inherited them. With ongoing governmental support there would be opportunities to test new strategies, include a strong research component and integrate improved strategies into the program. Because of the current experimental nature of the programs and large potential benefits in terms of reduced pesticide use and increased output of lint, a strong case can be made for continued governmental support.

There are benefits of programs other than those quantified in this study and discussed above. From the integrated pest management programs good, consistent and improved area wide data are made available. These data are being used in research. The impact or benefits of the data thus provided to research will not be directly quantifiable or identifiable but will lead to future improved pest management tactics. Therefore, benefits of governmental involvement in pest management programs include: (1) program improvement or refinement, (2) research on improved pest management practices, (3) provide exposure to new clientele and (4) establish standards of performance through program evaluation.

One specific example of research related to integrated pest management programs involves the systems analysis work. The models being developed for a cotton production system have, as a result of ongoing programs, an improved data base. Through the systems analysis work, important variables and relationships are identified. This provides a two-phased benefit. First, the systems analysis research indicates data that are important to developing integrated pest management programs and should be a part of data collection in existing programs and also identifies some data that are being collected that are not of major use. Secondly, from relationships that have been identified, improved strategies for insect control can and have been incorporated into pest management programs.

FUTURE DIRECTION OF INTEGRATED PEST MANAGEMENT

Integrated pest management will continue to be on an area or regional basis to service the specific climatic and production problems of an area. These programs can be expected to become much more (and most are already evolving) than an insect control program. It is imperative the overall production system be included. Pest management programs will become production systems and include consideration and recommendation relative to crop rotation, cultural practices, varieties, fertilization and irrigation practices. To develop systems with optimum production characteristics will require close coordination of soil scientists, entomologists, plant pathologists, economists, animal scientists, etc. Some examples of where progress along these lines is being made is in the Rio Grande Valley, Pecos ar California programs.

The production systems will likely be developed in an area through an intensive research and extension effort. Demonstration of the program, once developed, would best be on a block of land large enough so that non-participants' actions would have a minimal effect. Within the control area, near 100 percent producer cooperation would be required. The program could gradually be total producer responsibility with the demonstration block moved to new locations in the area in a manner that would maximize efficiency of adoption by all producers in the region.

Looking to other opportunities in integrated pest management, the use of satellites (ERTS) can be expected to become an integral component. Through this monitoring system, insect outbreaks or movement, disease, and crop stress can be identified for a region and early countering actions taken.

EXPANSION TO OTHER CROPS

Integrated pest management programs are currently being effectively applied in several production systems. Some of these other crop programs are to be evaluated under this particular contract (peanuts and tobacco).

Limitations need to be established for expansion to other crops. An integrated pest management program must be specifically designed for an area. Therefore, a program will differ among regions for the same crop. Crops other than cotton have different biological characteristics and pest problems, hence a cotton program is not directly applicable to other crops. For example, the emerging greenbug problem in the Texas High Plains with possible development of resistance by the greenbug requires a unique program approach. A program incorporating the principles of scouting, selective insecticide application and improved cultural practices is required to effectively cope with the problem. However, the exact practices and recommendations will not necessarily parallel any cotton program.

Another concept that is disturbing is the consideration of integrated pest management programs on a commodity basis. A preferable concept is an integrated pest management program for a region that includes all agriculture in that region. For example, the cotton insect management program in the Blacklands included several thousand acres of grain sorghum for 1974. This is due to the contribution of grain sorghum in providing beneficials to cotton and interrelations of cotton and grain sorghum production. In an integrated pest management program, it is often difficult to ignore all but one crop in an area.

This indicates some general thoughts relative to integrated pest management. Being more specific, components of integrated pest management programs are considered.

Monitoring of pest and beneficial species is, of course, essential to any successful program. Greenbug problems in grain sorghum and wheat require periodic population determination to avoid serious damage to the crop. More importantly, with much more serious long run implications, population assessment is needed to avoid (1) unnecessary insecticide applications and (2) use of excessive quantities of insecticide. By "overspraying", development of resistance by the insect is likely. There is some evidence the greenbug in grain sorghum on the Texas High Plains is currently developing resistance to insecticide. There is no need to elaborate on the undesirability of this phenomenon in terms of reduced output, increased producer costs and drastic increases in quantity of insecticide that would be expected in response to resistance. The date of initiation, timing and specific insects and/or diseases monitored for would be a function of the crop and the area.

Cultural practices, including crop rotation, are important parts of a pest management program. For example, a reduced plant population in grain sorghum would improve effectiveness of insecticides applied for greenbug. However, tradeoffs between reduced greenbug damage but a lower potential yield need to be quantified.

Seed variety selection is useful in a pest management program. Where short season cotton appears to be desirable for the Rio Grande Valley, grain sorghum varieties resistant to greenbug are needed on the Texas High Plains. Grain sorghum seed with indicated resistance is being introduced by the Texas Agricultural Experiment Station through commercial seed companies on a limited basis in 1975. Again, the point is that a particular commodity program must be developed based on characteristics of that crop.

From the cotton program, the keys to success of a program apply to other crops. For example, a pest management program needs (1) the support of a strong producer group, (2) individual producer support and participation and in most cases (3) nearly 100 percent producer participation to gain the benefits of an area-wide program. The third point is especially important for crops grown in large acreages throughout an area. Without participation and support by the vast majority of producers, non-participant actions will often nullify effectiveness of many program strategies.

The results of the Texas cotton programs indicate the type of benefits that can be expected by applying integrated pest management programs to other crops. Cotton is, however, associated with the use of the largest quantities of insecticide. This is due to the magnitude of pest problems. Cotton was selected for early emphasis because the potential for benefits was greatest. Although benefits are being achieved by the cotton program, there is opportunity for even more impressive benefits of an integrated pest management program.

The benefits or results of the cotton program are not directly applicable to most other crops because the potential level of benefits is not as great. This is not to say integrated pest management programs are not needed for other crops, but that benefits per dollar of program cost will likely not be as great.

In conclusion, a very rapid payoff attributable to integrated pest management programs should not be expected. The 1972 cotton insect management program had little measurable effect while the 1973 program showed positive effects on output and producer net returns indicating acceptance by producers of some program strategies. A cursory review of the 1974 program indicates even greater acceptance by producers and in turn larger benefits. Time and demonstration of effectiveness is important in influencing producers,and gaining acceptance of integrated pest management strategies is a gradual process.

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Appendix E-i

EVALUATION OF PEST MANAGEMENT PROGRAMS FOR PEANUTS IN TEXAS AND OKLAHOMA

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R. D. Lacewell
J. E. Casey

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Table of Contents

Page

Acknowledgements i

Introduction E-1

Major Programs E-2

I. Frio County Program E-3

  Program Characteristics E-4

  Users and Location E-6

  Assessment E-7
    Biological effectiveness E-7
    Costs and returns E-8
      Implementation E-9
      Operation E-9
      Producer E-12
    Environmental implications E-14

  Program Feasibility and Expansion E-16

II Comanche County Peanut Pest Management Program E-19

  Program Characteristics E-20

  Users and Location E-23

  Assessment E-25
    Biological effectiveness E-25
    Costs and returns E-29
      Implementation E-29
      Operation E-30
      Producer E-32

Table of Contents Concluded

Page

Environmental implications E-32

Program Feasibility and Expansion. E-34

III. Oklahoma Program E-39

Program Characteristics E-40

Users and Location E-41

Assessment E-43
Biological effectiveness E-43
Pest management program E-43
Hughes County Demonstration Farms E-46
Costs and returns E-48
Implementation E-48
Operation E-48
Producer E-50
Environmental implications E-51

Program Feasibility and Expansion E-53

Overall Feasibility E-56

Expansion to Other Crops E-57

References E-62

List of Tables

Table E-1 Distribution of growers by number of peanut acres in the Frio County Program, 1971-74 . . . . E-7

Table E-2 Total peanut production and pounds with a quality reduction due to burrowing bug damage, 1970-74, Frio County, Texas E-8

Table E-3 Estimated implementation costs of the Frio County peanut insect survey program E-10

Table E-4 Frio County peanut insect survey program operation costs by source of funds E-11

Table E-5 Pounds of peanuts damaged by the burrowing bug and resulting loss in producer revenue for Frio County, 1970-74 . . . . E-14

Table E-6 Acres of peanuts in the Frio County program treated with insecticides E-15

Table E-7 Quantity of insecticides used by participating peanut producers in the Frio County program, 1971-74 . . . . E-17

Table E-8 Number of producers, fields and acres participating in the Commanche County peanut pest management program, 1973 . . . . E-24

Table E-9 Average 1973 yield of participating producers and the county and 1971-72 average yield of participating producers E-27

Table E-10 Estimated implementation costs of the Commanche County peanut pest management program E-29

Table E-11 Commanche County peanut pest management program cost by source of funds, 1973 . . . . E-31

Table E-12 Number of producers according to use of recommended pest management practices, 1973 . . . . E-36

Table E-13 Acres of peanuts on the eight farms in the 1973 Oklahoma peanut pest management pilot program E-42

Table E-14 Reported grades and yields for irrigated and non-irrigated peanuts in the Oklahoma pest management program, 1973 . . . . E-44

Table E-15 A comparison of acres treated with chemical pesticides to acres receiving no treatment in the Oklahoma pest management program, 1973 . . . . E-45

Table E-16 A per acre comparison of management strategies on a peanut pest management demonstration farm in Hughes County, Oklahoma, 1973 . . . . E-47

Table E-17 Oklahoma peanut pest management program costs by source of funds, 1973 . . . . E-49

Table E-18 Chemical cost, by category, for four pest management strategies used on the Hughes County peanut demonstration farm, 1973 . . . . E-53

INTRODUCTION

Pests associated with peanut production include plant diseases, nematodes, weeds and insects. In the production and marketing of peanuts there are two equally important factors, yield and quality. In some cases, satisfactory yields are obtained but lower prices associated with quality reductions significantly affect crop profitability. The burrowing bug, Pangaeus bilineatus (Say), has caused serious quality losses in some production areas (Smith, Horden and Pitts). Of course, there is also the yield consideration in that insects such as the lesser cornstalk borer, Elasmopalpus lignosellus (Zeller), can reduce yields 50 percent or more.

Research entomologists have determined that about 35 insects feed on the peanut plant (Smith and Haney). Of these, only two (lesser cornstalk borer and burrowing bug) consistently require insecticide application for control. Natural biological control agents such as parasites, predators and pathogens usually maintain the other insects at a sufficiently low level that insecticide treatment is not economically justified.

However, producer efforts, beginning in 1968 and 1969, to control the lesser cornstalk borer and burrowing bug created an overuse of insecticides in Texas and created favorable conditions for population outbreaks of secondary pests (Smith and Haney). Some secondary insects that reached population levels which required insecticide use included corn earworms, armyworms, cutworms and tobacco budworm.

Since key insects and growing conditions differ by area, integrated pest management programs (IPM) for peanuts must be area or regionally oriented to address particular pest problems. This report considers three integrated pest management programs in Texas and Oklahoma. Published reports and data gathered as part of the IPM programs provided the basis for this evaluation.

MAJOR PROGRAMS

There are two IPM programs in Texas and one in Oklahoma included in this report. One Texas program, termed Frio County Program, was initiated in 1971 with all scouting costs paid by producers. The principal problem in Frio County peanut production is maintaining quality of the product.

The other two IPM programs, one each in Texas and Oklahoma, are a part of the multistate-multicrop federally supported integrated pest management program. These programs were initiated and are being directed by the State Agricultural Extension Service largely with cooperative grant funds provided by the U.S. Department of Agriculture.

These two federally supported peanut pest management programs began in Texas and Oklahoma in 1973. This limited period of program operation in addition to the problems incurred in the first year of any large program place severe limitations on this evaluation. In 1973, there were no control groups, hence, no basis for making any comparisons. The 1974 operation of the Texas and Oklahoma programs were significantly altered from 1973. This means there is no control group data for making comparisons and the basic 1973 program operation is no longer being followed. This emphasizes the need to consider 1974 results in establishing viability and feasibility of these two IPM peanut programs. An annual report for 1974, prepared by IPM program leaders will be available in 1975.

I. FRIO COUNTY PROGRAM

Frio County is an important producer of peanuts in Texas. Yields generally vary between 2,000 and 2,500 pounds per acre (Texas Department of Agriculture). Changes in yield primarily reflect climatic growing conditions, i.e., insects and diseases have a lesser effect on yield.

The key insect of peanuts in Frio County is the burrowing bug. This insect does not significantly affect yield, but rather causes a reduction in quality which has an associated lower price. The effect on total and net producer returns can be very large (Smith, Horlen and Pitts).

Although the burrowing bug has been around for a long time, the first recognized damage from it occurred in 1968 in Frio County (Smith and Hamman). Peanuts are not the native host of the burrowing bug. There have been infestations in Georgia, Florida and Alabama but seldom are they severe enough to justify chemical control. There is generally little known about the insect or why it shifted to peanuts as a host in Frio County.

The 1968 infestation and large quality losses represented the beginning with the burrowing bug again causing large quality losses in 1970. Producers reacted to the burrowing bug problem by applying insecticide. Their efforts to control key pests created additional problems and resulted in an overuse of insecticides (Smith and Haney).

Burrowing bugs pierce the peanut hull and draw juices from the kernel (Smith and Hamman). This causes yellow spots or pitting of the kernel which cannot be detected until the kernel is removed.

After the 1970 year and incurring ineffective control of burrowing bug damage as reflected in quality related income losses, the Frio County Peanut Improvement Association approached the Texas Agricultural Experiment Station for recommendations. The resulting recommendation consisted primarily of a scouting program.

PROGRAM CHARACTERISTICS

Under the direction of the Frio County Peanut Improvement Association, with assistance by the Texas Agricultural Experiment Station and Texas Agricultural Extension Service, a scouting program was initiated for peanut production in Frio County. All costs associated with scout teams were paid by the producers. This cost has been $1.00 per acre scouted for 1971-74.

Fields are scouted weekly (Smith and Harlan). First scouts look for evidence of the burrowing bug, and if found, estimate infestation level. In addition, other insects included in the report are thrips, leafworms, lessor cornstalk borer and other insects. Insecticide application, if needed, is a decision of the responsible entomologist. Scouts also obtained production characteristics, rotation history, insect history, fertilizer program, disease control, insect control and irrigation or rainfall received for each field included in the program.

Entomologists with the Texas Agricultural Extension Service were responsible for meeting periodically with scout teams to provide assistance in solving problems, making insecticide control recommendations and releasing weekly results of insect survey team findings. This program is primarily producer supported and directed with publically supported scientists providing recommendations and guidance. This minimizes overhead to the program but keeps the most knowledgeable scientists involved to maximize effectiveness of the program.

An objective of this program was to avoid unnecessary use of insecticides including unneeded treatments for non-economic pests as well as reducing quality losses caused by the burrowing bug. To reduce quality losses caused by the burrowing bug, timing of insecticide application was found to be most important. Damage was minimized when insecticide was applied at initial invasion (Smith, Horlen and Pitts). Delaying treatment until nymphs appeared resulted in large quality losses even though good burrowing bug control was achieved. Thus, for this program to be successful producers need timely information on burrowing bug infestations. This is accomplished with insect survey (or scouting) teams.

There is also a strong research program of the Texas Agricultural Experiment Station in Frio County. Scientists involved in this research program are asked to provide recommendations and suggestions to the scout or survey program. The research component is effectively used to refine and redirect the producer program as results indicate possible improvements. This, therefore, is a useful relationship for research and producers in that producers rapidly gain benefits of new research results and researchers have access to more data.

USERS AND LOCATION

This insect survey program was initiated and is conducted by the Frio County Peanut Improvement Association. The program is contained within Frio County, Texas, which is located 30 miles southwest of San Antonio. There are about 18,000 acres of peanuts produced annually in Frio County with all but about 1,000 acres irrigated (Texas Department of Agriculture). Average irrigated peanut yield per acre from 1969-73 was about 2,600 pounds compared to about 1,000 pounds on non-irrigated land (Texas Department of Agriculture).

Acres of peanuts included in the program were 5,984 in 1971, 6,590 in 1972, 6,558 in 1973 and 5,923 in 1974. Average field size across all years has been approximately 90 acres (Smith and Horlen).

The distribution of participating producers by acres of peanuts in the program is presented in Table E-1. Total number of participating producers has declined from 28 in 1971 to 19 in 1974. The number of producers that have from 51 to 200 acres in the program has remained fairly constant, while there has been a decline in number of producers with 200 or more acres that participate in the program (Smith and Horlen).

Table E-1. Distribution of growers by number of peanut acres in the Frio County program, 1971-74[a]

Peanut acreage distribution	Number of producers			
	1971	1972	1973	1974
0 - 50	1	1	0	0
51 - 200	13	11	11	11
201 and greater	14	13	12	8

[a]Source (Smith and Horlen)

ASSESSMENT

Biological effectiveness

The key insect of peanuts in Frio County has been the burrowing bug since 1968 (Smith, Horlen and Pitts). Producers acting individually, without periodic insect surveys, were using excessive quantities of insecticide, using less than optimum timing of treatments and not obtaining desirable control to reduce burrowing bug related quality losses. By instigating periodic insect survey of fields and using expert entomological assistance in deciding on treatment, pounds of peanuts incurring quality losses were reduced.

Since the burrowing bug does not affect yield, the measure of program success is in pounds of peanuts that incur a quality loss. Table E-2 indicates total production and pounds with a reduced quality primarily due to the burrowing bug.

Table E-2. Total peanut production and pounds with a quality reduction due to burrowing bug damage, 1970-74, Frio County, Texas

Yield	Production[a]	Reduced quality[b]	Reduced quality as percent of total production
	(1,000 lbs)	(1,000 lbs)	(percent)
1970	46,521	9,020	19.39
1971	46,000	97	0.21
1972	40,950	60	0.15
1973	50,465	0[c]	0.00

[a] Source (Texas Department of Agriculture).

[b] Source (Smith and Haney).

[c] There was no penalty assessed for eleven loads that had some burrowing bug damage (Jordon).

These data indicate that the insect survey program was successful in reducing the pounds of peanuts that were damaged by the burrowing bug from over 9 million pounds to less than one million pounds or from nearly 20 percent of total production to less than one percent of total production.

Costs and returns

Costs and returns associated with the Frio County peanut program are divided into implementation cost, program operation cost and producer net return implications.

Implementation: Peanut producers in Frio County approached the Texas Agricultural Experiment Station in 1970 for recommendations as to means of controlling quality losses caused by the burrowing bug. An insect survey program was recommended and a delegation of authority suggested (Smith and Horlen). The proposal was accepted by the producers and they assumed responsibility for initiation and operation of the program. This producer accepted responsibility is reflected in the implementation cost shown in Table E-3.

By pricing a scientific man day at $153 ($40,000 for a scientific man year), total implementation costs, not including producer costs, were $2,109. This included time meeting with the Frio County Peanut Improvement Association and training the first four scouts.

Operation: The association assumes most of the responsibility for this program and pays all scout costs. Therefore, the only governmental related costs are in the form of time entomologists direct to making recommendations to producers and suggested changes in the overall program, as indicated by the research component.

Table E-4 shows operation costs of the program and an allowance for entomological time. Input by the Texas Agricultural Experiment Station and Texas Agricultural Extension Service is fairly stable among years and is estimated at $459 and $865 annually, respectively. Included in the Texas Agricultural Extension Service cost is a supply of paper and forms for the program (estimated to be $100).

Table E-3. Estimated implementation costs of the Frio County peanut insect survey program[a]

Item	Unit	Price per unit	No. of units	Total cost	Source of funds	
					TAES[b]	TAEX[c]
Entomologist	SMD[d]	153	9	1,377	459	918
Travel	mile	.12	1,000	120	0[e]	120
Scouting Training	SMD[d]	153	4	612	306	306
Total				2,109	765	1,344

[a] Source (Smith).

[b] Texas Agricultural Experiment Station.

[c] Texas Agricultural Extension Service.

[d] Scientific man day.

[e] Travel in area was connected with research program.

Table E-4. Frio County peanut ins[illegible]vey program operation cost by source of funds[a]

Item	Unit	Cost per unit	No. of units	Total cost	Source of funds		
					TAES[b]	TAEX[c]	Producer[d]
Entomologist[e]	SMD[f]	153	8	1,224	459	765	0
Scout							
1971	man	1,786	4	7,150	0	0	7,150
1972	man	1,488	4	5,951	0	0	5,951
1973	man	1,640	4	6,558	0	0	6,558
1974	man	1,481	4	5,923	0	0	5,923
Supplies[g]	program	100	1	100	0	100	0
Total							
1971	program	8,474	1	8,474	459	865	7,150
1972	program	7,275	1	7,275	459	865	5,951
1973	program	7,882	1	7,882	459	865	6,558
1974	program	7,247	1	7,247	459	865	5,923

[a] Source (Smith).

[b] Texas Agricultural Experiment Station

[c] Texas Agricultural Extension Service.

[d] Producer costs at $1.00 per acre.

[e] Average annual cost

[f] Scientific man day.

[g] Average annual cost.

Producer cost of the program varies as acres in the program vary. Acreage in the program averages about 30 percent of total peanut acres or around 6,000 acres. Since producers contribute $1.00 per acre for periodic insect surveys, this places their cost at about $6,000 per year. This total program cost is about $7,324 annually for 6,000 program acres. The producer contribution pays all costs of insect survey teams.

Total annual cost per acre for this program is about $1.22 of which around $0.22 is governmental support in the form of entomological recommendations. The producer contribution, since implementation, covers all scouting costs including training of new personnel.

Producer: This program was initiated by producers due to substantial revenue losses attributable to peanut quality reductions caused by the burrowing bug. Therefore, the effect of the program on producers if reflected in the reduction of pounds of peanuts damaged and consequent reduction in revenue losses. Altough there is the increased cost to producers of $1.00 per acre for program cost (periodic insect survey), insecticide usage has been reduced via the program more than sufficient to offset program cost. Therefore, this evaluation will focus on increased revenue due to the reduction in pounds of peanuts damaged by the burrowing bug.

With the burrowing bug feeding on peanuts, yellow to dark spots are produced on the kernel (Smith, Horlen and Pitts). This is termed "pitting" by peanut graders. Direct penalty losses to producers are based on the percent of kernels damaged. The direct revenue loss or penalty for "pitted" peanuts can range from $3.40 per ton (for two percent damaged kernels) to $100 per ton (for ten percent damaged kernels) (Smith, Horlen and Pitts).

There is another producer cost incurred due to damaged peanuts in Frio County. The County does not have facilities for damaged peanuts, hence, they have to be stored and then shipped to another location. This process can delay harvesting and in storage peanuts incur some aging. This will further reduce the value of the product.

Table E-5 indicates pounds of peanuts damaged by the burrowing bug and associated reduction in producer revenue in 1970 (year without the program) and 1971-74 (years with the program). The difference between 1970 losses and 1971-73 losses is an estimate of increased producer net revenue due to the program.

Reduction in Frio County producer revenue in 1970 due to damaged kernels was about $122,000. In 1971 and 1972, burrowing bug populations were similar to those experienced in 1970 but revenue losses due to damage kernels were reduced to about $1,000. In 1973 and 1974, burrowing bug populations were less than 1970, hence the direct comparisons are more difficult.

This evaluation indicates that in years when burrowing bug populations are relatively high, benefits of the program are $120,000 or more. This benefit or increase in producer net revenue is somewhat less for other years but estimated to be in excess of $20,000. In summary.

Table E-5. Pounds of peanuts damaged by the burrowing bug and resulting loss in producer revenue for Frio County, 1970-74[a]

Item	Unit	No program 1970	With program 1971	1972	1973	1974[c]
Damaged peanuts	(lb)	9,020,000	97,064	60,000	nil	nil
Damage to producers	($)	121,770	1,309	900	0	0
Program benefits[b]	($)	NA	120,461	120,870	121,770	121,770

[a] Source (Smith and Haney).

[b] Based on reduction in damaged peanuts (reduced loss) compared to 1970. Burrowing bug populations in 1971 and 1972 were comparable to 1970 (Smith), while they were lower in 1973 and 1974. This suggests a possible over estimate of benefits in 1973 and 1974.

[c] Projected as of September 23, 1974, with the majority of peanuts harvested.

for the four program years (1971-74), even if benefits were zero (an unrealistic assumption) in light infestation years (1973-74), average annual benefits of the program would be over $60,000. This indicates the program is successful in improving producer net revenue from peanuts in Frio County.

Environmental implications

This program was initiated by producers to obtain effective control of the burrowing bug. With research in the area and scientists involved in the program, there was an opportunity to develop a program which would result in effective insect control and reduce unnecessary use of insecticides. The program began in 1971. Table E-6 shows pre-emergence and post emergence acres treated with insecticides for 1971-74.

Scientists feel that, based on research, there was unnecessary use of insecticides before crop emergence (Smith). Table E-6 data indicates program success in reducing acres treated (from 5,011 in 1971 to 2,494 in 1974).

Table E-6. Acres of peanuts in the Frio County program treated with insecticides[a]

	Acres treated	
Year	Pre-emergence	Post-emergence
1971	5,011	6,629
1972	3,952	5,478
1973	3,175	1,012
1974	2,494	2,634

[a] Source (Smith and Horlen).

Post-emergence treatments are needed for burrowing bug control. Therefore, acres treated and quantity of material used is expected to vary with infestation levels. Acres treated post-emergence declined from a 1971 high of 6,629 to 1,012 in 1973. There was an increase in acres treated post-emergence in 1974 to 2,634.

Shifting from acres to quantity of material used, Table E-7 indicates pounds of insecticide applied pre-emergence, post emergence and in total. For pre-emergence insecticide use, the quantity applied has declined from 5,729 pounds in 1971 (0.96 pounds per acre) to 2,828 pounds in 1974 (0.48 pounds per acre). This is a 50 percent reduction in quantity of materials used and indicates that the program is successful in reducing unnecessary insecticide use pre-emergence.

Post-emergence insecticide use has also shown over 50 percent decline since program initiation. In total, insecticide use on the approximately 6,000 program acres has been reduced from 18,627 pounds to around 7 to 8 thousand pounds. The first year (1971) was one of gaining producer confidence with the next few years showing the results of field surveys as a part of pest management decisions.

With some 30 percent of Frio County peanut acreage in this program, the program influences production decisions throughout the County. Therefore, the trend of pesticide use is a relevant measure of program success, rather than what the typical producer would have done in the absence of a program. The data indicate success in reducing insecticide use while reducing pounds of peanuts adversely affected by the burrowing bug.

PROGRAM FEASIBILITY AND EXPANSION

This is an integrated pest management program initiated and operated by peanut producers. About 30 percent of the peanut acreage of Frio County is included. Principally those producers with burrowing bug problems participate in the program.

Table E-7. Quantity of insecticides used by participating peanut producers in the Frio County program; 1971-74[a]

Year	Pre-emergence		Post-emergence		Total	
	Total	Per acre[b]	Total	Per acre[b]	Total	Per acre[b]
	pounds					
1971	5,729	0.96	12,898	2.16	18,627	3.12
1972	6,471	0.98	9,594	1.46	16,066	2.44
1973	4,303	0.66	2,024	0.31	6,327	0.97
1974	2,828	0.48	5,268	0.89	8,096	1.37

[a] Source (Smith and Horlen).

[b] Per acre pounds of insecticide used based on total acres in the program (5,984 in 1971, 6,590 in 1972, 6,658 in 1973, and 5,923 in 1974).

Program cost to producers is $1.00 per acre. Total annual cost of the program is approximately $6,000 for producers and $1,324 for both the Texas Agricultural Experiment Station and Texas Agricultural Extension Service. Annual program benefits are estimated between $60,000 and $120,000. This suggests that cost effectiveness of this program is from $8 to $16 return per one dollar of program cost. In addition to monetary gains, there is a significant downward trend in quantity of insecticides used.

This particular program was initiated in the private sector of the economy and has remained there. It is relatively stable at 6,000 acres and producer costs have not increased above $1.00 per acre. There is good evidence, if insect survey costs warranted, producers would be willing to pay $2.00 or more per acre to continue the program.

Based on this evaluation and producers reaction to supporting the program, it can comfortably be classified as viable. Since this program can be viewed as a viable program currently being operated in the private (commercial) sector of the economy, it is useful to identify strong components useful in directing development of other IPM programs. First, the problem (burrowing bug) emerged as a new problem where its consequences were highly visible. This provided a rallying point for cooperation and identified a place where producers could profitably use assistance. Many pest problems emerge gradually (or they are in existence in the beginning) and potential benefits are not clearly obvious to producers.

Second, and highly important is a strong producer organization carrying the thrust of the program (Frio County Peanut Improvement Association). A viable, strong producer organization continually surfaces as an integral factor in successful IPM programs.

Lastly, the program has a principal insect survey scout. This individual is a school teacher, hence has summers available for this program. He trains new scouts, provides leadership and shows devotion to the responsibilities of the position. This is an important factor in the success of this program.

II. COMANCHE COUNTY PEANUT PEST MANAGEMENT PROGRAM

In 1968 and 1969, lesser cornstalk borer control was identified as being the key insect pest problem for many peanut producers in the Comanche County area. Producer efforts to control the lesser cornstalk borer (which causes yield reductions) with insecticides were resulting in outbreaks of secondary pests because of environmental disruption. Lesser cornstalk borer infestations can cause normal dryland yields in the area to be reduced from 50 to 60 bushels per acre to 10 bushels or less, thus the producer has strong economic incentives to control this pest (Hines, Hoelscher, Curtis and Frisbie). Insecticide treatments by air were being made at regular interval regardless of the infestation level. Less than desirable control was resulting from these automatic applications as the quantity of insecticide used was greatly increased (Smith and Haney). Texas Agricultural Experiment Station and Texas Agricultural Extension Service personnel began working with producers by making suggestions on timing for insecticide applications, appropriate delivery system (ground rig rather than aerial) and on the appropriate quantity and type of insecticide to be used. This educational effort was very successful in causing a shift from aerial application of insecticides to ground application. During the production years, 1970 to 1971, respectively, the percent of insecticide applications applied by aerial methods declined from 81 percent to 18 percent in the area studied (Smith and Haney).

This rather general educational program initiated changes in the method of application and resulted in more effective use of insecticide and minimized environmental effect on biological control systems of secondary pests. However, general area wide recommendations on when to treat are associated with severe limitations. Biological diversity present in the area must be defined on an individual field basis. A periodic insect survey of each field is needed for maximizing net returns for the producer and obtaining proper insect control. This was the need that the Peanut Pest Management Program for peanut producers in Comanche County was designed to fill. The program was to aid in management decisions which reduce crop injury from all pest problems.

PROGRAM CHARACTERISTICS

The pilot peanut pest management program in Comanche County began during the 1973 growing season (Hines, Hoelscher, Curtis and Frisbie). This program was designed to demonstrate management techniques available to control plant diseases, nematodes, weeds and insects. Specific program objectives in 1973 were to (1) gain producer confidence in integrated pest management techniques, (2) use field scouts to monitor pest populations on an individual field basis and report results to cooperating producers, (3) inform producers of pesticide efficacy and cost-profit relationship of production practices, and (4) provide a total approach to pest management which includes plant disease, nematode, soil fertility, weed and insect control (Hines, Hoelscher, Curtis and Frisbie).

Cooperators in this program include the Texas Agricultural Extension Service (TAEX), Texas Peanut Producers Board, Texas Department of Agriculture and the County Program Building Committee of the TAEX in Comanche County and local peanut producers. Farmers in each of three community areas of Comanche County were chosen by the Comanche County Program Building Committee and contacted during a series of spring meetings. Program fields were located by the Area Extension entomologist, County Extension entomologist and County Extension Agent.

This program is a cost-sharing educational program with peanut producers contributing $0.25 per acre for scouting costs. The contribution was to give the producers a vested interest in the program. Producer funds were collected by Texas Peanut Producers Board.

The technical support team involved in program development included an entomologist, agronomist, plant pathologist and economist-management specialist. In addition, three field scouts were employed that had field experience in peanut production in the local area.

Weekly field scouting was conducted for ten weeks with participating producers provided weekly information on pest development in their fields. Each field scout surveyed about two fields per day and some 435 acres on a weekly basis. This is small compared to other commodities because of the complexity of data to be obtained. Consequently scouting required two to four hours per field. Late season field problems were checked by the County Extension entomologist. Scout training was done in a classroom and on a regular basis in the field by scientists of the Texas

Agricultural Extension Service and Texas Agricultural Experiment Station (Hines, Hoelscher, Curtis and Frisbie).

Results of weekly field surveys were evaluated jointly by the peanut growers and the County Extension entomologist. Decisions on the need for pesticide treatment was made by the grower after pest population data were assimilated and compared to economic threshold levels.

Included in the field survey for insects were lesser cornstalk borers and leaf feeding insects, cutworms, armyworms, and cabbage loopers. In the insect survey process, scouts inspected plants for the presence of plant diseases. In addition, weeds that escaped routine herbicide application in each field were recorded. Primary weed problems included nutsedge, purple nightshade and butter daisy. Weed species and density were recorded to develop a weed history or each field. These data were not provided on a weekly basis to producers.

Nematode samples were taken approximately 40 days after planting and at pre-harvest. The plant pathologist contacted producers where sample results indicated a nematicide treatment would provide economical returns. Sample results of nematode populations were provided to growers within three weeks after soil sampling (Hines, Hoelscher, Curtis and Frisbie).

The outline of this program indicated that it was devised to include overall management aspects of production. Cultural control practices are a major control procedure used for various pests and do not add to production costs. Several pests of peanuts were monitored and several disciplines were involved at the initiation of the program.

With regard to health questions, blood cholinesterase monitoring and urine analysis was conducted for scouts and County Extension entomologists.

USERS AND LOCATION

Comanche County is located halfway between Fort Worth and San Angelo. There are approximately 57,000 acres of peanuts produced in the county annually, one of the largest peanut allotments in the United States (Texas Department of Agriculture). In 1973, supplemental irrigation was applied to 45 percent of the county acreage (Texas Department of Agriculture).

For the period 1969-73, an average of 79 million pounds of peanuts were produced on 56,820 acres (Hines, Hoelscher, Curtis and Frisbie). This amounts to an average per acre yield of 1,390 pounds and has ranged from a low of 1,097 pounds in 1971 to a high of 1,877 in 1972. At a price of $0.18 per pound for peanuts this amounts to $250 per acre or a contribution of over $14 million for the total county economy.

In 1973 the program consisted of 33 producers participating with a total of 42 fields and 1,315 acres of peanuts. Both irrigated and non-irrigated peanut farms were included in the project.

The total acres farmed by each participating producer in 1973 were not obtained as part of the program. Even though specific comparisons of farm size for participating and non-participating producers cannot be made, generally, participating producers include the larger farm operators. These producers did not typically place all of their peanut acreage in the program, but rather those fields where they experienced the greatest production problems with pests. About 65 percent of the fields in the program were less than 50 acres and only one was larger than 100 acres; i.e., 35 percent were larger than 50 acres in size.

Environmental, ecological and biological differences in the county were identified for program operation. Because of differences in planting dates, soil types, seed varieties, planting rates, harvesting practices and water management, three separate communities were identified for program implementation. Area I is the Sidney-Beatlie community, Area II the DeLeon community and Area III the Gustine and Proctor communities. The distribution of participating producers by fields, acres and irrigation designation are shown in Table E-8 (Hines, Hoelscher, Curtis and Frisbie).

Table E-8. Number of producers, fields and acres participating in the Comanche County peanut pest management program, 1973[a]

Area	Producers	Number of fields Irrigated	Non-Irrigated	Total	Acreage
I	11	6	12	18	488
II	12	10	4	14	436
III	10	8	2	10	391
Total	33	24	18	42	1,315

[a] Source (Hines, Hoelscher, Curtis and Frisbie).

Area II is the hub of the county and accounts for about 45 percent of total county peanut acreage. Thirty three percent of program acres are in this area.

ASSESSMENT

This program was initiated in 1973 and did not begin until the crop year had begun. This represents a limitation to potential effectiveness since producers had already been involved in pest management. In addition there was no control group which is needed for comparisons and there were some personnel difficulties experienced in 1973 (these are discussed later in this section). Given the limitations underlying this analysis, assessment of the 1973 Comanche peanut pest management program will include biological effectiveness, program implementation costs, program operation cost, producer cost and returns implications and environmental implications.

Biological effectiveness

Although there was no control group in 1973, there are some comparative measures of participating growers yields that provide some general indications of program effect on yield.

Production records for 1973 producers were not obtained until 1974. This is due to a personnel problem in the program which lead to the resignation of the individual responsible for field operations. Replacement personnel were then faced with the task of operation for the 1974 program as well as backtracking to gather data on 1973 operation. Data relative to production in 1973 on participating fields is based on 20 participating producers that responded to a questionnaire (13 did not respond). Included were seven non-irrigated fields and 13 irrigated fields.

The average weighted 1973 yields for participating producers (non-irrigated and irrigated) as well as average 1973 county yields and average yields for the same producers and fields for 1971-72, are presented in Table E-9. For participating producers, the reader is reminded that generally they are the better managers, but they place fields with the greatest pest problems in the program. This makes interpretation difficult since average county yield may not be a valid comparison. Also year to year variations in yields are such that comparisons among two or three years does not provide a sound basis for establishing program effect. Weather conditions during the production and harvest season greatly influence pest problems and ultimately crop yields.

The 1973 average yield for participating producers (irrigated and non-irrigated) exceed both the same producers average yield for 1971-72 and average county yield. For non-irrigated production, the participating producers' yield was 12 percent higher than their 1971-72 average yield and 29 percent higher than the 1973 county average. Irrigated fields in the program showed a 9 percent increase in yield over 1971-72 and 14 percent increase above 1973 average county yield. The previous limitations, of course, apply, but these yield data strongly

Table E-9. Average 1973 yield of participating producers and the county and 1971-72 average yield of participating producers

Item	Yield Non-irrigated	 Irrigated
	-------pounds	per acre------
Participating producers[a]		
1973	1,425	2,216
1971-72	1,267	2,038
County average - 1973[b]	1,101	1,950

[a] Source (Curtis). Based on 7 non-irrigated fields and 13 irrigated fields.

[b] Source (Texas Department of Agriculture).

suggest the 1973 peanut pest management program in Comanche County did result in a yield increase on those fields in the program.

As a part of internal evaluation, average yield for a sample of participating growers and sample of non-participating growers (10 in each sample with 5 non-irrigated and 5 using irrigation) were compared (Hines, Hoelscher, Curtis and Frisbie). These data indicated an average yield for participating producers of 1,917 pounds valued at $268.38 compared to non-participating grower average yield of 1,835 pounds valued at $256.90. The implication is an 82 pound per acre yield increase and $11.48 increase in income.

A major objective of this program was to assist producers in timing pesticide applications. Considering insecticide use for control of the lesser cornstalk borer and applying the concept of economic thresholds, the number of fields treated can be compared to the number of fields exceeding economic threshold levels. Area I had 11 fields treated with eight exceeding the economic threshold, Area II treated one field with eight above the economic threshold and Area III treated 14 fields with two exceeding the economic threshold. Area production differences are emphasized by these data. Area II is a low net return area and reluctant to use costsly chemicals while Area III producers rely heavily on a regular schedule or calender date for chemical use regardless of pest population.

Regarding fungicidal applications, even though there was an average of 2.5 per field, there is a producer reluctance to use fungicides. Research data indicate many producers could greatly increase yields and grades with improved use of fungicides to control various leaf and pod diseases (Hines, Hoelscher, Curtis and Frisbie).

Nematode samples were taken at pegging time and at preharvest. At pegging, 24 fields were infested with nine needing treatment while at harvest 26 were infested and five needed treatment. Suggestions were made by the County Extension entomologist, with aid from the Area Extension pathologist, to producers relative to treatment. Three fields were treated at pegging time and one field at preharvest. There is no evidence to support any advantage of treating at preharvest, hence, it is suggested that producers not treat at preharvest even with heavy infestations (Hines, Hoelscher, Curtis and Frisbie).

Costs and returns

This program began in June 1973. This means some costs were incurred prior to this time. Program costs are separated into implementation and operation.

Implementation: Estimated implementation costs of the Comanche County peanut pest management program are presented in Table E-10 by source of funds. Total implementation costs are an estimated $17,250. Of this, the Texas Agricultural Extension Service incurred $9,950 (57 percent), the Texas Agricultural Experiment Station $5,000 (30 percent) and Federal Cooperative Agreement funds $2,300 (13 percent).

Table E-10. Estimated implementation costs of the Comanche County peanut pest management programs[a]

Item	Source of funds		
	Grant[b]	TAEX[c]	TAES[d]
	--------------dollars------------		
Mapping	0	250	0
Grower contact	0	1,200	0
Recruiting	0	500	0
Scout training	500	1,000	1,000
Developing forms	600	1,000	500
Data processing	0	500	500
Area delineation	0	500	0
Procedure and development	1,200	5,000	3,000
Total	2,300	9,950	5,000

[a] Source (Hoelscher, 1974).

[b] Cooperative funds from U.S. Department of Agriculture.

[c] Texas Agricultural Extension Service.

[d] Texas Agricultural Experiment Station.

Operation: Implementation costs allocated to Federal Pest Management Grant funds are not included in operation costs. The 1973 program costs, by source of funds, are presented in Table E-11 and are for the period June 1 to December 31, 1973.

Total operating costs in 1973 were $37,833. Of this, Federal Pest Management Grant funds incurred $8,683 (23 percent), Texas Agricultural Extension Service $15,850 (42 percent), Texas Agricultural Experiment Station $11,000 (29 percent), APHIS $2,000 (5 percent), and participating producers $300 (less than one percent).

This indicates a rather substantial financial commitment by the Texas Agricultural Extension Service and Texas Agricultural Experiment Station. As evidence of program benefits become available, a greater percent of program costs need to be shifted to producers.

With a total cost of $37,833 and 1,315 acres in the program, total project cost per acre was $28.77. This magnitude of per acre costs are considered excessive for a viable program. The reason per acre costs were this high was time required to survey each field (two hours) and small acreage in the program. The per acre cost is being significantly reduced in 1974 and with improved scouting procedures developed, the per acre costs should be significantly reduced each year as the program operation is streamlined.

In addition to direct program operating costs, there is a significant peanut research program of the Texas Agricultural Experiment Station in this area and result demonstration plots of fields supported

Table E-11. Comanche Country peanut pest management program cost by source of funds, 1973[a]

Item	Souce of funds					
	Grant[b]	TAEX[c]	TAES[d]	APHIS[e]	Producer	Total
	--------------------dollars--------------------					
Salary						
County Extension entomologist	3,934	0	0	0	0	3,934
Scouts	2,386	0	0	0	300	2,686
Secretary	892	0	0	0	0	892
Employee benefits	1,000	0	0	0	0	1,000
Travel						
County Extension entomologist	403	0	0	0	0	403
Scouts	879	0	0	0	0	879
Supplies and material	229	0	0	0	0	229
Equipment	700	0	0	0	0	700
Regulatory personnel	0	0	0	2,000	0	2,000
Personal health monitoring	400	0	0	0	0	400
Other	160	0	0	0	0	160
Area entomologist	0	4,250	0	0	0	4,250
County Extension agent	0	4,000	0	0	0	4,000
Extension Crop Specialist	0	6,400	0	0	0	6,400
Extension administration	0	1,200	0	0	0	1,200
Supporting scientists	0	0	11,000	0	0	11,000
Less implementation cost	-2,300	0	0	0	0	-2,300
Total	8,683	15,850	11,000	2,000	300	37,833

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[a] Source (Hines, Hoelscher, Curtis and Frisbie).

[b] Cooperative funds from U.S. Department of Agriculture.

[c] Texas Agricultural Extension Service.

[d] Texas Agricultural Experiment Station.

[e] Animal and Plant Health Inspection Service, U.S.D.A.

by the Peanut Producer's Board.

Producer: Without a control group, it is difficult to establish program effect on producer net returns. Based on the sample of ten participating and ten non-participating producers, the program resulted in an increase in per acre net returns of $11.48 (Hines, Hoelscher, Curtis and Frisbie).

Using the 1973 yield increases above the producers 1971-72 average as shown in Table E-9 and assuming no change in production costs with peanuts $0.15 per pound, program acres would be associated with an increase in per acre net returns of $22.12 on non-irrigated land and $26.70 on irrigated land. Compared to the county average, the net return increases would be $48.60 on non-irrigated land and $39.90 on irrigated land. It is not likely that the increase in net returns due to the program are as large as indicated comparing to the county average yield.

Basically, the evidence indicates participating producers had an increase in per acre net returns as a result of the program but there exists little basis for quantifying the amount. Net returns were probably not increased by as much as per acre program costs.

Environmental implications

Pesticide use in 1973 is separated into insecticides, herbicides, nematocides, and fungicides. There was a total of 1,658 pounds of insecticide used by participating producers in 1973, or 1.26 pounds per program acre (Hoelscher, 1973). Accumulated total program acres treated with insecticide were 1,208 (there were 1,315 acres in the program).

A total of 645 pounds of herbicides were applied or .5 pounds per program acre (Hoelscher, 1973). Accumulated total program acres treated were 1,232. Treatment on the acres was recommended through the program.

A total of 1,388 pounds of nematocides were applied. This amounts to 1.06 pounds per acre (Hoelscher, 1973). Accumulated total program acres treated were 314.

A total of 8,621 pounds of fungicides were applied, or 6.56 pounds per program acre. Accumulated total program acres treated were 3,538.3 or each acre was treated an average of 2.7 times. Interestingly, the accumulated acreage on which fungicide treatment was recommended was 9,658 or average of 7.3 times per acre.

Considering all of these chemicals together, a total of 12,312 pounds of pesticides were applied in 1973 on 1,315 acres. This means 9.36 pounds of pesticides were applied per acre. Of this 9.36 pounds, fungicides comprised 6.56 pounds or 70 percent. Also, this is with a fungicides use rate below that recommended in the program.

Regarding environmental implications of the program, there is some indication producers are more effectively using pesticides. The field surveys suggested that 90 percent of the fields did not need insecticide treatment. There were only six fields of the 42 that received two or more insecticide applications. In previous seasons, producers in this area have applied 10 to 12 applications of insecticide (Hines and Hoelscher). Participating producers followed program suggestions for pesticide applications on 46 percent of the irrigated peanut fields and 38 percent of the dryland peanut fields. There were 508 acres that received no insecticides, 17 acres received no fungicides and 1,047 acres received no nematocides (Hoelscher, 1973).

Without a control plot, quantitative comparisons of program effect on use of pesticides and associated yield and net returns can not be made. In general terms, even with a late start in 1973, evidence indicates that the program was successful in building producer confidence and demonstrating to them benefits of the integrated pest management program.

To evaluate environmental implications of the program, 25 soil samples were taken during the 1973 program. The analysis of these soil samples will be available in 1975.

PROGRAM FEASIBILITY AND EXPANSION

The Comanche County peanut pest management program was associated with two particularly significant limitations in 1973. First was the late start and being put in a position of playing catch up. An integrated pest management program needs to begin with educational activities before seed bed preparation. Producers must receive training during the planning stage for a crop which is planted in the spring of the year. With this limitation, the authors would be comfortable classifying all 1973 program costs as implementation.

Secondly, the person most responsible for maintaining close producer contact and creating producer confidence lacked enthusiasm relative to that phase of the position responsibility. The result was several participating producers never met the individual. This has created hardships in that the replacement has had to backtrack to gather 1973 data for this and other evaluations, carry out position responsibilities on the 1974 program and also make the grower contact necessary in a viable program.

In addition to the program limitations above, a limitation to this analysis is the lack of a control group. Therefore, given these limitations and only 1973 program results to use as a basis, it is difficult to proclaim whether or not this is a viable program. Before any such evaluation can objectively be made, 1974 program results must be reviewed.

However, even with these several severe limitations of the 1973 program, there are many program characteristics that are exciting and appear to have great potential. Of primary importance, this is structured as a truly interdisciplinary integrated pest management program. There will naturally be some difficulties and conflicts to be resolved, but with the potential payoff, time should be provided for this evolution. Through this one program, recommendations are made to producers relative to insecticide use, herbicide use, nematocide use, fungicide use and fertilizer use. This implies a total production system and the program is showing success at getting all the components to work together.

There is some evidence that the 1973 program developed producer confidence even with the personnel problem that was mentioned. For example, Table E-12 shows the number of producers by reaction to recommended pest management practices. In general terms about 40 percent of the producers followed all pest management recommendations, about 50 percent followed some recommendations and 10 percent followed no recommendations.

Table E-12. Number of producers according to use of recommended pest management practices, 1973[a]

Item	Followed all recommendations	Followed some recommendations	Followed no recommendations
Insects and mites	14	17	2
Diseases	10	21	2
Nematodes	20	11	2
Fertility	8	17	8

[a] Source: (Hoelscher, 1973).

Another major indicator that the 1973 program developed producer confidence, and strong indication that this is likely evolving to a viable program, is returning participating growers in 1974. The 1974 program has 30 of the 33 producers in the program in 1973, as well as 13 new growers. There is a net increase in number of participating growers of ten with program acreage increased from 1,315 to 2,800 acres. Total program costs in 1974 will be approximately the same as 1973. Costs of the program per acre will be almost 50 percent less.

In 1974, participant growers cost for the program was increased from $0.25 per acre to $1.00 per acre. Growers questioned about the change generally indicated they would be willing to pay for all scouting costs up to $3.50 per acre. It is expected scouting costs will be considerably less than $3.50 in 1975.

Other major changes for 1974 which look most promising include (1) improved sampling procedure, (2) use of three-wheel motor bikes in fields which reduces scouting time in a field by 50 percent, (3) a program of grower education during non-production periods of the year and (4) complete records and use of a control group.

The new sampling procedure for lesser cornstalk borer along with the three-wheel bikes (ten growers have also purchased bikes for their use in checking their peanut fields) are estimated to reduce scout costs to $3.50 per acre or $11.37 per acre total cost. Each man is scouting 464 acres in 1974. Further per acre program cost reductions are anticipated for 1975.

Increased producer contact through programs, newsletters and farm visits can be expected to have a desirable effect on producers level of participation and decision making process.

For 1974, complete records are being maintained for participating and a sample of non-participating producers relative to production practices, pesticides used, costs and yield and grade of peanuts. A comparison will be made between participants and non-participants as well as participants following recommendations and participants not following recommendations.

Expansion of this program will be from 1,315 acres in 1973 to 2,800 acres in 1974 with a goal of 7,000 acres for 1975. These acreage increases are required to get per acre costs into a meaningful range.

In conclusion, although there is not appropriate data available for 1973 to establish viability of this program, the progam and personnel changes for 1974 and preliminary review of 1974 operations indicate most promising results. The potential of this program and new innovative techniques being developed are deserving of continued support.

III. OKLAHOMA PROGRAM

Peanut production is important in many Oklahoma Counties. In 1969, there were 1,372 farms that produced 195,212,577 pounds of peanuts on 115,[illegible] acres (U.S. Department of Commerce). Based on $0.15 per pound, this suggested an agricultural crop worth $29,281,886 annually to Oklahoma.

The Oklahoma peanut crop is affected by a wide variety of pests, any one of which can significantly reduce quality and/or quantity. Oklahoma producers have a history of pest problems that includes root lesion nematode (*Pratylenchus brachyurus*), lesser cornstalk borer (*Elasmopalpus lignosellus*), red-neck peanut worm (*Stegasta bosqueella*), various foliage feeders, Cercospora leaf spots, and Southern Blight (*Sclerotium rolfsii*).

In 1973, the Oklahoma State University Extension Service initiated a program designed to achieve more efficient pest management in peanut production.

Among the benefits of the first year of this program was the discovery of "web blotch" (*Ascochyta* sp.) by field scouts on demonstration farms. With verification of the existence of web blotch in Oklahoma, a monitoring system was set up and a state wide program to control web blotch initiated. Evidenced indicates that the disease was effectively controlled. Nevertheless, the 1973 Oklahoma peanut program generated considerable grower enthusiasm and for 1974 major shifts in emphasis occurred.

PROGRAM CHARACTERISTICS

The Oklahoma program in 1973 was a pilot program using a systems approach with chemical and cultural control practices (Sturgeon, Tripp, Coakley and Greer). The major objective was to obtain effective control with minimum pesticide input. For the 1973 pilot program, only 995 total acres with 394 monitored acres were included in the program. Several reasons contributed to the limited monitored acres in the first year. The project was approved late, there were many miles between the farms and Stillwater, and it was undetermined how many acres a monitoring team could handle (Sturgeon, Tripp, Coakley and Greer). The distance to Stillwater was a limitation of the program as the samples had to be returned to lab facilities.

Once every two weeks the farms in the program were surveyed and the grower given a "field report." This was followed by a "laboratory report" giving the results of nematode analysis and disease identification not found at the time of the survey. At each farm visit or survey the crop was checked for health, soil fertility, nematode and insect populations, and diseases and weeds present.

The two reports (field and laboratory) given to growers indicated the infestation levels of each pest or pathogen found. Treatment was recommended based on specified so called "economic threshold levels." It was suggested that treatments use the minimal quantity of pesticide that would be adequate for control.

The 1973 Oklahoma peanut program was largely a demonstration program due to late approval. Four levels of pest management were considered in 1973. Random field plots were established to demonstrate the effects of the four management strategies. In an effort to promote the program ground-level infrared and color photos were used to show results at grower meetings. Records for each plot were maintained for chemical application, hoeing time, yield and quality, disease, and weed control ratings. Using this procedure, each of the different management strategies could be compared. Per acre costs were estimated and returns estimated based on the value of the different yields and qualities (Sturgeon, Tripp, Coakley and Greer).

USERS AND LOCATION

The 1973 Oklahoma peanut pest management program was designed as a pilot program with plans for expansion in subsequent years. The demonstration program was carried out in Atoka, Hughes, and Marshall counties under supervision of the Oklahoma Cooperative Extension Service. A total of eight farms were in the program (Table E-13). This included 995 acres of peanuts with 394 acres actually monitored or periodically surveyed (Sturgeon, Tripp, Coakley and Greer). Total acres were low due to the program limitations listed above. The capabilities of the monitoring team were undetermined, thus acres were limited to prevent overextending the team (Sturgeon). However, by the end of the season the team was monitoring a 400 acre field near Kingston, Oklahoma and were following the area movement of "web blotch". Results of the monitoring team indicate one team could effectively monitor 1,200 - 2,000 acres per week (Sturgeon, Tripp, Coakley and Greer).

The eight farms with 394 monitored acres included five farms of irrigated peanuts. Total irrigated acres were 324 while total dryland acres were 69 acres (Sturgeon, Tripp, Coakley and Greer). Table E-13 shows the total acres, monitored acres, and distribution of acres by irrigation practice.

Table E-13. Acres of peanuts on the eight farms in the 1973 Oklahoma peanut pest management pilot program[a]

Farm	Total acres	Monitored acres	Irrigated acres	Non-irrigated acres
1	192	192	192	0
2	70	12.4	12.4	0
3	62	16	0	16
4	182	42	42	0
5	115	30	30	0
6	250	16.3	0	16.3
7	87.2	48.3	48.3	0
8	37	37	0	37
Total	995.2	394	324.7	69.3

[a] Source (Sturgeon, Tripp, Coakley and Greer).

In Hughes County a demonstration farm was established as part of this program to evaluate and compare various chemical and cultural practices (Sturgeon, Tripp, Coakley and Greer). The farm was located near Calvin, Oklahoma. Over [illegible] area producers visited the farm. In late August, 82 growers were given a special tour of the demonstration farm. The interest shown by area producers indicates that future programs would be well received in this area of the state.

ASSESSMENT

This program was initiated after production began in 1973. Growers were already involved in pest management for the production year, thus the late start presented a severe limitation to potential effectiveness. In addition, no control group was established in 1973 that could be used for [illegible]. Included in this evaluation, which is divided into the four areas, are biological effectiveness, program operation costs, producer costs and returns implications, and environmental implications.

Biological effectiveness

The absence of a control group made yield comparisons difficult for the 1973 pest management program. However, a comparison of results on the demonstration farm in Hughes County will provide an indication on the quantity of management practices.

Pest Management Program: A summary of yields and grades is given in Table E-14 for the eight farms in the pest management program. Irrigated production showed a high of 4,020 pounds per acre and a low of 2,640 pounds per acre, with the average for the five farms 2,973 pounds per acre. Under non-irrigated production, the largest yield reported was 2,970 pounds per acre. The low was 1,920 pounds per acre, with the average 2,490 pounds per acre. Peanut grades ranged from 53 percent to 76 percent with the average 68 percent on irrigated production. Non-irrigated production showed a grade range of 68 percent to 72 percent with the average for the three farms 70 percent.

Table E-14. Reported grades and yields for irrigated and non-irrigated peanuts in the Oklahoma pest management program; 1973[a]

Unit	Unit	Irrigated			Non-irrigated		
		Low	Average	High	Low	Average	High
Yield	pounds	2,640	2,973	4,020	1,920	2,490	2,970
Grade	percent	53	68	76	68	70	72

[a] Source (Sturgeon, Tripp, Coakley and Greer).

A major objective of the 1973 program was to apply pesticides only when specified economic threshold levels were exceeded. A key problem was to keep producers from over-reacting when applications were recommended. A summary of pest control by use of chemicals is given in Table E-15 As would be expected, weed control was practiced on all irrigated acres, but 22 percent of the non-irrigated acres (16 acres) did not use chemical weed control measures. Low populations of lesion nematode were found throughout

Table E-15. A comparison of acres treated with chemical pesticides to acres receiving no treatment in the Oklahoma pest management program; 1973[a]

Item	Acres treated		Acres not treated	
	Irrigated	Non-irrigated	Irrigated	Non-irrigated
Weed control	324	55	0	16
Nematode control	239	16	85	53
Insect control	240	0	84	71
Soil Fungi control	132	16	192	55
Leafspot control	324	71	0	0

[a]Source: [illegible]

the season. Eighty-five acres of irrigated peanuts and 53 acres of non-irrigated peanuts were not treated for nematode control in 1973. Insect populations were carefully monitored with insecticides applied only when needed as determined by population levels. None of the 71 surveyed acres of non-irrigated peanuts were found to need insecticide treatment. Only 74 percent of the irrigated acres were treated. Traditionally, insecticides were used heavily and program leaders indicated some difficulty in convincing growers that less insecticide was needed.

Leafspot control was practiced on all acres, both non-irrigated and irrigated, due to early occurrence and continued development under conducive weather conditions. One grower did not follow the program recommendation for leafspot control and suffered severe defoliation. However, most growers followed suggestions on closing spray intervals and accomplished adequate leafspot control with minimal applications (Sturgeon, Tripp, Coakley and Greer).

Other pest problems included the appearance of Southern Blight. This disease became severe enough to warrant treatment by fungicide on only four farms. Moderate early infestations of thrips were encountered, but not considered economically damaging enough to justify pesticide treatment. The Red-neck peanut worm caused some damage (Sturgeon, Tripp, Coakley and Greer).

Hughes County Demonstration Farms: The primary objective of the farm in Hughes County was to demonstrate the effectiveness of different chemical and cultural managerial practices. The four management practices were designated as A, B, C, and D. A brief characteristic description of each is given below. Management level A plot was characterized by application of chemical practices recommended for the area regardless of need (pest and disease intensity). Management level B received treatment only when periodic field survey data indicated control was needed and emphasis was placed on minimal pesticide usage. Level C was characterized by practices considered typical for area producers. Level D received little or no pesticide applications (Sturgeon, Tripp, Coakley and Greer).

The results of the four demonstration plots are given in Table E-16. It is readily seen from Table E-16 that management strategy A has

Table E-16. A per acre comparison of management strategies on a peanut pest management demonstration farm in Hughes County, Oklahoma; 1973[a]

Strategy	Yield	Grade	Returns	Total cost	Net returns
	pounds	percent	----dollars	per acre	------
A	4,370	67	684	275	410
B	2,746	68	432	187	245
C	2,274	66	354	186	168
D	1,697	59	243	105	138

[a] Source (Sturgeon, Tripp, Coakley and Greer).

the highest output and net returns. The results of this demonstration among the four plots and pest management practices provides strong evidence to producer practices of continuing to apply pesticides on a calender basis rather than based on field survey data. These results are somewhat disturbing. They indicate that either (1) integrated pest management is not needed in Hughes County or (2) the level of pest or disease intensity established as sufficient to require control is too high; i.e., control is needed sooner, or (3) the quantity of herbicide, insecticide or fungicide recommended is too low to be effective. This result is most important and should be closely investigated. Development of the basis for establishing need for control and some implications are discussed later in this section. Regarding the results of the Hughes County demonstration plots, important limitations include a single year experience and no replications. This makes it impossible to draw statistically significant conclusions and suggests a real need for research to quantity relationships.

Cost and returns

This program began late in 1973, thus some costs were incurred prior to this time.

Implementation: Specific data on implementation of this program were not provided. However, since the total for 1973 is similar to Comanche County Texas, a similar implementation cost is expected. Program implementation costs in Comanche County, Texas were $17,250. This figure is assumed to be relevant for the Oklahoma program.

Operation: The 1973 program costs, by source of funds, are presented in Table E-17 and are shown as revised in April of 1973.

Total operating costs in the proposed budget were $41,000 (Taggart). Of this, $12,400 (30 percent) were cooperative grant funding, $5,600 (14 percent) were funds of the Oklahoma State University Extension Service, $3,000 (7 percent) were funds of the Oklahoma Agricultural Experiment Station, and $20,000 (49 percent) were from the Hughes County peanut growers for field support. The $20,000 is primarily support for the Hughes County demonstration farm.

The participating producer did not incur any of the 1973 cost in Oklahoma. However, as will be discussed later, a plan has been devised

Table E-17. Oklahoma peanut pest management program costs by source of funds, 1973[a]

	Source of funds				
Item	Grant[b]	OAEX[c]	OAES[d]	Hughes Co. peanut growers	Total
Salary					
Time plant health specialist 9 months @ $400 3 months @ $500	5,100	0	0	0	5,100
Field Scout 40 hour week @ $2.10 hour	1,500	0	0	0	1,500
Secretarial	1,200	2,000	0	0	3,200
Employee benefits	700	0	0	0	700
Travel	2,000	600	0	0	2,600
Supplies	1,000	0	0	0	1,000
Health monitoring	300	0	0	0	300
Data process	600	0	0	0	600
Extension Specialist	0	3,000	0	0	3,000
Environmental monitoring	[e]	0	0	0	0
Research support	0	0	3,000	0	3,000
Field support	0	0	0	20,000	20,000
TOTAL	12,400	5,600	3,000	20,000	41,000

[a] Source (Taggart).

[b] Cooperative funds from the U.S. Department of Agriculture.

[c] Oklahoma State University Extension Service.

[d] Oklahoma Agricultural Experiment Station.

[e] Animal and Plant Health Inspection Service, U.S.D.A., provided the monitoring support.

by which the producers will share the program costs. Also, it is emphasized that the Oklahoma State University Extension Service had only $12,400 to develop a program that was approved late and many miles separated the plots from the University lab at Stillwater.

Considerable additional funding has been made available for 1974 for a more extensive pest management program. A later discussion will describe some of the 1974 program changes.

Producer: Without a control group, it is difficult to estimate the effects of the program on grower net returns. Data were not available for the eight farms under the team monitoring program. The only comparisons of cost and returns to the producer are those estimated for the demonstration farm in Hughes County. Table E-16 gives estimates of costs and returns for the four management strategies. Net returns were estimated to be the highest under level A which, as indicated earlier, is a regularly scheduled pesticide application scheme. Level B, which applied pesticides based on need (pest or disease intensity) showed net returns per acre of $245 or $175 below the net returns for level A. This discrepancy calls for research to explain the reasons for the difference and readdress the current recommendations. It is imperative to a successful program that recommendations relative to pest control be effective in maintaining or increasing producer net returns. Level C, which corresponds most closely with current practices in the area, had net returns per acre of $243 less than plot A and $77 less than plot B. The last strategy (plot D) had net returns of only $138 per acre or $272 below level A.

Environmental implications

Strategy B has been described as a program of application based on need rather than a "needed or not" approach. It is worthy to note how need for control was established. Need for chemical control of pests or disease was based on historical applications of the area; i.e., a rule of thumb method for recommendation. Thus, strategy B can hardly be distinguished from strategy C. This is not a strong scientific method of establishing a basis for recommending when to use chemicals for pest and disease control.

Since strategy A is a program of automatic applications of chemicals regardless of need, it is expected that there are opportunities to maintain or increase net returns with less pesticides or increase net returns through more effective use of the pesticides. However, many factors will enter the production process and these estimates were taken from small demonstration plots. The 1974 pest management program was designed to search for high returns strategies with the goal of minimal pesticides introduced into the environment. It is interesting to note that integrated pest management strategies for Hughes County can be expected to significantly increase yields, but there will be a increase in traditional quantities of pesticides used. This implies that for effective control and to increase yields and net returns, use of more pesticides will be required. This type result should not be a problem if goals of the program are efficient and effective use of pesticides.

Chemical use varied from essentially no chemical controls on plot D to automatic or calendar based chemical applications on plot A. The chemical cost is used as a proxy for quantity to compare the different strategies. Table E-18 shows the chemical cost subdivided into control categories. Total chemical costs are substantially greater in plot A than any of the other plots (nearly twice that of B and C). The major differences in A and B or C is a large increase in insect and nematode control agents and growth regulators. Only a slight difference between program B and C chemical costs is indicated, thus further verifying the position that B is virtually no different from C.

The team monitoring program in the three Oklahoma Counties found that some chemical treatments could be avoided whereas in previous years the growers would have applied chemicals much as done in plot A on the demonstration farm. Indications are that growers responded favorably and were willing to accept the team's suggestions (Sturgeon).

Without a control plot, quantitative comparisons of program effect on use of pesticides and associated yields and net returns cannot be made. Further, the program has been drastically adjusted for 1974, hence, the 1973 program did not, in effect continue. This means 1973 results are not particularly applicable to the remainder of the program. That is, this program now must be evaluated based on 1974 program results due to adjustments that have occurred.

Table E-18. Chemical cost, by category, for four pest management strategies used on the Hughes County peanut demonstration farm, 1973[a]

Item	Demonstration plot			
	A	B	C	D
	dollar per acre			
Fertilizer	8.20	4.50	4.50	4.50
Leafsopt control	39.38	39.38	32.11	6.66
Soil Fungicide	21.50	21.50	6.60	0
Insect and Nematode control	50.90	2.48	1.24	0
Weed control	13.94	13.94	9.39	0
Growth regulator	22.50	0	0	0
Gypsum	3.50	0	0	0
Total chemical cost	159.92	85.30	53.84	11.16

[a] Source (Sturgeon, Tripp, Coakley and Green).

PROGRAM FEASIBILITY AND EXPANSION

The effectiveness of the 1973 Oklahoma pest management was limited by three significant factors. Initially, the project was late being approved, thus the production process had already begun. Secondly, the distance between Stillwater and the monitoring sites created a major inconvenience. The third limitation was the inability to judge how many acres a monitoring team could survey effectively.

In addition, the analysis lacked a control group thus making comparisons of effectiveness impossible. Given these limitations, it is difficult to determine whether this is a viable program. Before any such evaluation can objectively be made, 1974 program results must be reviewed.

However, even with these limitations the program seems to hold promise for improving Oklahoma peanut production. As with many pest management programs, this will be an interdisciplinary integrated pest management program. Recommendations will be made to growers concerning insecticide use, herbicide use, nematode use, fungicide use, and fertilizer use. Economic analysis of results will be presented such that growers can see the effectiveness of all programs. From 1973 results, it is expected that to increase yields and net returns, an increase in the use of pesticides will evolve, compared to traditional practices.

In 1973, Oklahoma State University extension scientists gained grower support and confidence through grower meetings and personal contacts. Many area growers visited the demonstration plots and have committed acres for the 1974 program (Sturgeon).

The pilot program of 1974 will provide private grower counseling and a field monitoring service to implement an integrated control system approach to pest management (Sturgeon). Suggestions will be made to cooperators based on populations of harmful and beneficial insects, weeds, nematodes, and diseases found. Similar to 1973, a major emphasis will be minimal use of pesticides in controlling pests. A total plant health approach will be taken.

The 1974 program is offered to the Hughes County Growers Association for a per acre fee. Participants will receive a variety of services including individual consultation, farm designed program, computerized data record system, individual farm records, farm visits by specialists, and weekly field monitoring by a plant health team (Sturgeon).

Field monitoring will be done by two-man scouting teams once a week from June through August and once every two weeks in September and October. Plant health hazards such as soil fertility, water quality, nematode and insect populations, disease and weeds will be identified (Sturgeon). Subsequent to each visit a "field report" will be presented to each grower. The field report will be supported by a mobile plant health diagnostic lab with a technician and field plant health supervisor (Sturgeon). It is assumed the mobile diagnostic laboratory would operate similar to the one that has been successfully used at VPI[1/] for many years. The cost of the lab and field scouts will be covered by a grower service fee of $8 per acre for the first 50 acres, $7 per acre for the next 25 acres, and $6 per acre for the balance of acres the grower has in the program.

In 1974, the availability of trained personnel will limit the expansion of the program. However, as trained personnel become available the program will be expanded over the state (Sturgeon). Proposals for 1975 include adoption of multi-crop pest management programs. Presently 1975 plans call for private counseling, mobile lab, and field monitoring for alfalfa, cotton, soybean, peanuts, and wheat (Sturgeon).

1/VIP = Virginia Polyechnic Institute

In conclusion, there is not appropriate data available for 1973 to establish if this is a viable program.

Furthermore, the adjustments made in 1974 are ambitious and exciting. Participating growers are contributing $8 per acre to the program which includes a mobile laboratory. The program is going to expand into several crops and include several phases of production. The changes made and planned hardly relate to the 1973 program. Therefore, we strongly suggest 1974 program results be reviewed to establish viability of this program.

OVERALL FEASIBILITY

The two peanut pest management programs using federal pest management grant funds (Comanche County program and Oklahoma program) were implemented in 1973 and did not begin until during the growing season. For each of these programs, there was no control group for evaluating program effectiveness. Further, this report had to be completed before 1974 program results were available. Lastly, there were major significant shifts in both programs from 1973 to 1974. Therefore, it would be inappropriate to attempt to establish program feasibility based on data available at the time of this analysis. It is critical that 1974 be included in any such evaluation.

However, using Frio County program data and viewing 1974 Comanche County and Oklahoma program direction, there is a sufficient basis for recommending temporary continuation of the programs. New innovative techniques are being tested, pest management strategies involving several phases of production and several disciplines are being applied and producer cooperation is encouraging.

Data being obtained in these programs can be most useful in establishing management/yield relationships and in identifying managerial and production practices that are conducive to (or help prevent) quality losses. This means there is a need to couple a strong research program with these producer oriented programs to investigate such relationships as weather factors and leaf blight, etc.

In conclusion, these programs were implemented on a very ambitious basis. An attempt is being made to eliminate several steps in the process of moving to a truly integrated pest management program. This means there will be some problems, but many years of evolution may be skipped. These programs should not be penalized for this ambition. Lastly, the Frio County program over a four year period has demonstrated feasibility of integrated pest management for peanuts. The vast majority of program funding is currently provided by producers. Based on the Frio County evaluation, it is reasonable to expect a maturing of the other programs and demonstrated feasibility by the end of 1974 or 1975.

EXPANSION TO OTHER CROPS

Integrated pest management programs are currently being effectively applied to several crops. Some of these other crop's programs are to be evaluated under this particular contract (cotton and tobacco). The discussion included in the cotton evaluation is applicable to peanuts (Lacewell and Casey).

Limitations need to be established for expansion to other crops. An integrated pest management program must be specifically designed for an area. Therefore, programs for the same crop will differ among regions. Crops other than peanuts have different biological characteristics and pest problems, hence a peanut program is not directly applicable to other crops. For example, the emerging greenbug problem in the Texas High Plains with possible development of resistance by the greenbug requires a unique special program. A program incorporating the principles of scouting, selective insecticide application and improved cultural practices is required to effectively cope with the problem. However, the exact practices and recommendations will not parallel any peanut program.

Another concept that is disturbing is the consideration of integrated pest management programs on a commodity basis. A preferable concept is a integrated pest management program for a region that includes all agriculture in that region. For example, the cotton insect management program in the Blacklands included several thousand acres of grain sorghum for 1974. This is due to the contribution of grain sorghum in providing beneficials to cotton and interrelations of cotton and grain sorghum production. In an integrated pest management program, it is often difficult to ignore all but one crop in an area.

This indicates some general thoughts relative to integrated pest management. Being more specific, components of integrated pest management programs are considered.

Scouting is, of course, essential to any successful program. Greenbug problems in grain sorghum and wheat require periodic scouting to avoid serious damage to the crop. More importantly, with much more serious long run implications, scouting is needed to avoid (1) unnecessary insecticide applications and (2) use of excessive quantities of insecticide. By "overspraying", development of resistance by the insect is likely. There is some evidence that the greenbug in grain sorghum on the Texas High Plains is currently developing resistance to insecticide. There is no need to elaborate on the undersirability of this phenomenon in terms of reduced output, increased producer costs and drastic increases in quantity of insecticide that would be expected in response to resistance. The date of initiation, timing and specific insects and/or diseases scouted for would be a function of the crop and the area.

Cultural practices, including crop rotation, are important parts of a pest management program. For example, a reduced plant population in grain sorghum would improve effectiveness of insecticides applied for greenbug. However, tradeoffs between reduced greenbug damage and a lower potential yield need to be quantified.

Seed variety selection is useful in a pest management program. Where short season cotton appears to be desirable for the Rio Grande Valley, grain sorghum varieties resistant to greenbug are needed on the Texas High Plains. Grain sorghum seed with indicated resistance is being introduced by the Texas Agricultural Experiment Station through commercial seed companies on a limited basis in 1975. Again, the point is that a particular commodity program must be developed based on characteristics of that crop.

From the cotton and peanut program, the keys to success of a program apply to other crops. For example, a pest management program needs (1) the support of a strong producer group, (2) individual producer support and participation, (3) scientists willing to gain producer rapport through close producer contact and (4) nearly 100 percent producer participation to gain the benefits of an area-wide program. The fourth point is especially important for crops grown in large acreages throughout an area. Without participation and support by the vast majority of producers, non-participant actions will often nullify effectiveness of many program strategies.

The results of the Texas cotton programs and Frio County peanut program indicate the type of benefits that can be expected by applying integrated pest management programs to other crops. The benefits or results of the cotton program and Frio County peanut program are not directly applicable to most other crops.

In conclusion, a very rapid payoff to integrated pest management programs should not be expected. The 1972 cotton insect management program and 1973 peanut pest management program had little measurable effect while the 1973 cotton program and the expected results of the 1974 peanut program showed positive effects on output and producer net returns indicating acceptance by producers of some program strategies. Time and demonstration of effectiveness is important in influencing producers and gaining acceptance of integrated pest management strategies is a gradual process.

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Appendix F-i

EVALUATION OF THE PEST MANAGEMENT PROGRAM FOR TOBACCO IN NORTH CAROLINA

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Table of Contents

Page

I. Introduction F-1

II. Tobacco Insect Scouting F-5

III. Measures of Program Effects

A. Benefit Measures F-12

Cost Savings:

Yield Effects of Program Efforts F-14
Stalk Destruction F-19
Pest Management Adoption F-20

B. Program and Farm Costs F-22

C. Environmental Impact F-30

IV. Projections and Limitations F-33

References F-36

List of Tables

1.1 - Farm and Field Characteristics F-3

2.1 - County and State Scouting Loads F-6

2.2 - Comparison of Program and Census Farm Sizes F-8

2.3 - Pest and Beneficial Insect Counts F-9

2.4 - Economic Threshold Infestations per Field F-11

3.1 - Average Number Insecticide Applications per Threshold Report F-13

3.2 - Average Yields for 1969-1973 in Four Sample Counties for Program and Non-Program Farms F-15

3.3 - Results of Tests for Yield Effects F-16

3.4 - Seasonal Tobacco Scout Wage and Scout Travel Expenses per Field and per Acre F-23

List of Tables Continued

Page

3.5 - Total Program Costs per Field and per Acre F-28

3.6 - Estimated Tobacco Grower Costs for Insect Control F-29

3.7 - Mean Tiger Beetles per Field F-30

3.8 - Insecticide Applications and Pounds per Acre per Year on Program Farms by Counties F-32

North Carolina Tobacco Pest Management

I. Introduction

Tobacco is a highly managed crop which has a gross return of about $2,000 per acre. North Carolina is the leading state in output with about 375,000 acres. About 75 percent of all farm operators in North Carolina sell some tobacco. The major insect pests are budworms, Heliothis virescens, and hornworms, Manduca sexta. About 80 percent of the tobacco acreage is treated with insecticides each year according to USDA pesticide use surveys (USDA, 1974).

The USDA pesticide use surveys showed that tobacco was a heavy user of synthetic organic insecticides. In 1966 about 2.8 pounds of active material were applied per acre of tobacco grown in North Carolina. The estimate for 1971 was 2.0 pounds. The 1969 Census of Agriculture lists an average of $12.09 expended for insecticides per acre on those North Carolina farms which are primarily tobacco farms. The census also indicates that smaller tobacco farms may be using more insecticides than larger ones ($10.46 per acre for the 1124 largest farms, and $15.83 per acre for the 11,804 smallest farms.)

Pest management in tobacco production is not limited to insect control. Plant diseases such as brown spot (Alternaria longipes), root knot nematodes, black shank (Phytophthora parasitica), and mosaic, a virus disease, are controlled by resistant variety development and use. In 1969, 22 percent of all tobacco farms applied herbicides and 26 percent treated for nematodes (U. S. Census).

Because tobacco is grown by about seventy-five percent of all North Carolina farmers, much of the pest management training in the state affects tobacco production. Each year a pesticide school is held with about 300 participants. Research to support pest management training has been actively pursued by extension and research specialists. Economic thresholds for hornworms were established in research in the early 1950's and released in 1956. Early destruction of tobacco stalks has been promoted since the late 1940's for hornworm, nematode and root knot control. Plant pathologists have played a major part in encouraging plowing of stalks to control root knot. Food for overwintering hornworms is also affected by sucker control. Sucker control was done by laborers until MH30 came into use to save labor costs. Beginning in the early 1960's chemical sucker control has decreased area-wide hornworm populations substantially according to tobacco pest control specialists.

Beginning in 1971 pest management for tobacco insects and diseases in North Carolina was assisted by a grant from USDA. The program objectives were:

a) maximum natural suppression of pests by beneficial species;

b) application of selected insecticides only when pest populations exceeded economic thresholds as determined by weekly scouting;

c) effective sucker control executed through properly timed application of chemicals; and

d) early, thorough tobacco stalk destruction to reduce late season food supply to suppress overwintering pest populations and control tobacco diseases (Annual Reports, 1971, 1972, 1973)

These objectives were primarily designed to reduce unnecessary insecticide treatments to save growers production costs without a loss in tobacco yield or quality. Area-wide reduction in mean level of abundance of tobacco insect pests was anticipated from the stalk destruction, sucker control and maintenance of natural enemies.

Most of the resources of the pilot program were devoted to field scouting. Many small fields which were separately scouted led to large man-hour requirements. Table 1.1 shows that from 33 to 39 scouts were hired and trained to scout up to 3448 fields. The program operated in 1971 and 1972 in five counties and then was expanded to ten counties in 1973. Fewer but larger farms were

Table 1.1. Farm and field characteristics

Year	Number of scouts	Counties	Farms	Fields	Acres	Fields per farm	Acres per field	Sites per field
1971	37	5	1531	3,076	8,032	2.00	2.60	5
1972	39	5	1680	3,339	8,498	1.99	2.55	5
1973	33	10	813	3,448	11,350	4.24	3.29	4

a - Source: Annual Reports, 1971, 1972, 1973.

included in 1973. Average fields per farm went from about 2.0 to 4.24. Average acres per field increased from 2.6 to 3.29 acres. The farm and field size changes are important determinants of scouting costs, since scouting reports are made on each field and a report must be given to each grower.

The next section gives general information on the scouting and stalk destruction program. Section III gives estimates of grower and public costs in the program areas; benefit measures and environmental effects are also presented. The final section gives possibilities for expansion and limitations of the Tobacco Pest Management Program.

II. Tobacco Insect Scouting

Tobacco insect scouting to determine when a threshold level of pests is present had not been taught to growers or paid scouts prior to 1971 in any organized manner. Hiring and training was conducted by county agents and program professionals. During 1971, in the three regions scouts were assigned a work load of from 77 to 90 fields per scout for the season. Fields were checked once per week for 12 weeks.

Farms, fields, and acres per scout are shown in Table 2.1. The major change during the three years was a large increase in fields and acres per scout between 1972 and 1973. This was partly due to increased skills gained by two years of experience by some scouts, reduced number of sites per field in 1973 (from 5 to 4), larger fields, and piece-rate payment (by the field) rather than by the hour by three scouts in Wayne and Wilson Counties. The section on costs will examine the effect of fields per scout, farm size, and the change made in 1973 to reduce scouting costs.

Scout supervision in 1971 was limited to two USDA employees and one supervisor. Scout records on 19 percent of the fields in region II (Wayne-Wilson), 10 percent of the fields in Columbus-Bladen and 8 percent of the fields in Surry County were not completed. Scout supervision was increased in 1972. One local supervisor worked with each seven or eight scouts. A minimum of five quality control checks were made on each scout each week.

Participating farmers were not required to change their tobacco production practices to participate in the program. They merely were asked for their permission to have their fields scouted. In turn they received a report on pest and beneficial insect counts for each field each week. The report also gave the insecticide treatment threshold for each pest. From this information the grower could determine whether or not an insecticidal application was justified.

Table 2.1. County and state scouting loads[a]

County	Year	Scouts	Farms[b] per scout	Fields per scout	Acres per scout	Sites per field
Bladen	1971	7.0	44.1	77.0	180.9	
	1972	9.0	46.0	84.1	185.4	
	1973	6.5	28.5	96.2	223.1	
Columbus	1971	7.0	44.1	77.0	180.9	
	1972	7.0	39.1	71.3	167.3	
	1973	3.5	24.0	96.3	286.8	
Cumberland	1973	2.0	24.5	97.5	443.5	
Edgecomb	1973	2.0	21.0	99.0	696.0	
Jones	1973	1.0	25.0	96.0	452.0	
Lenoir	1973	2.0	17.5	91.5	468.5	
Nash	1973	1.0	12.0	92.0	395.0	
Surry	1971	7.0	32.5	89.9	179.3	
	1972	7.0	36.0	99.0	202.1	
	1973	4.5	29.1	132.7	266.7	
Wayne	1971	8.0	42.8	85.6	265.2	
	1972	8.0	46.3	86.9	265.2	
	1973	4.0	19.5	96.3	330.3	
Wilson	1971	8.0	42.8	85.6	265.2	
	1972	8.0	46.3	86.9	265.2	
	1973	6.5	26.5	113.8	355.2	
State						
	1971	37	41.2	83.1	217.1	5
	1972	39	43.1	85.6	217.9	5
	1973	33	24.6	104.5	343.9	4

a - From 1971, 1972 and 1973 Tobacco Pest Management Reports

b - Farms between 1971-1972 are not comparable with 1973. 1971-1972 refer to separate ASCS farms, 1973 farms refer to grower-operators.

Participating farms were generally larger than the average tobacco farm size. Table 2.2 shows that the ASCS farm size for the program farms was 5.3 acres in 1971 and 5.1 acres in 1972. However, an individual grower may have several ASCS farm numbers. In 1973 growers, not ASCS farms, were used for identification. The average grower size for the original five counties was 11.9 acres of tobacco and 14.0 acres overall in 1973. This is larger than the 7.7 acres on all North Carolina tobacco farms as determined by the 1969 Agricultural Census. Thus, in extending the results of the program to other areas of the state somewhat smaller farms and fields will be encountered.

Scouts recorded four major pests - budworms, hornworms, aphids and flea beetles. Four major beneficial species were also counted weekly. Phenological events such as planting dates, buttoning and plant size were recorded as they occurred. Dates of stalk destruction and comparisons with areas not in the program were conducted by a post harvest survey each year. Much of the effort in the first year was directed at developing a computerized record system. The record system was not operational until after the 1971 growing season.

Data on the pest numbers and two beneficial insects are given in Table 2.3. Pest populations were largest in the southern-most area I, intermediate in area II, and least in area III. Hornworm populations decreased in two areas and remained stable in area II between 1971 and 1973. Thus, there may have been some gain in meeting the objective of lowering mean level of abundance of this pest. Budworms increased in abundance in all areas between 1971 and 1973. The 1973 crop year was a particularly severe budworm infestation year for many crops in North Carolina.

Beneficial insects were not noticeably increased in the program areas. Only area II increased populations of both stiltbugs and *Campoletis*. Program

Table 2.2. Comparison of program and census farm sizes

County	Tobacco Acres Per Farm Program 1971 (farms)	 1972 (farms)	 1973 growers	 Census 1969 (farms)
Bladen	4.1	4.03	7.8	4.5
Columbus	4.1	4.27	12.0	5.6
Cumberland	a	a	18.1	6.3
Edgecombe	a	a	39.1	9.9
Jones	a	a	18.1	8.2
Lenoir	a	a	26.8	10.2
Nash	a	a	32.9	8.4
Surry	5.5	5.6	9.2	4.4
Wayne	6.2	5.3	16.9	7.1
Wilson	6.2	6.0	13.4	10.26
Mean	5.3	5.1	14.0	
State				7.7
Original Counties			11.9	

a - not in program

Table 2.3. Pest and beneficial insect counts[a]

		Hornworms	Budworms	Stiltbug	Campoletis
Area	Year	larvae/100 plants		adults/100 plants	cocoons/100 plants
I	1971	> 10	1.6	1.0	.05
	1972	7.0	4.0	.8	.2
	1973	4.5	6.0	.5	.05
II	1971	1.0	1.5	1.0	.3
	1972	2.2	1.8	1.0	.7
	1973	1.0	2.0	7.0	1.3
III	1971	.8	1.1	6.0	.8
	1972	.1	1.0	3.5	1.0
	1973	.25	2.0	2.5	1.5

a - approximations of seasonal means from figures in tobacco pest management reports 1971, 1972, 1973.

b - I - Columbus - Bladen Counties, II - Wayne-Wilson Counties, III - Surry County.

effects can not be separated from other effects on these populations.

Economic threshold levels of damaging pests were recorded for the program fields. Table 2.4 shows the average number of threshold reports per field by county. In 1971 and 1972 there were about .6 to .7 reports per field. This increased to 1.17 in 1973, mainly due to increased budworm populations as shown in Table 2.3. It should be noted that the thresholds themselves are specified with some amount of damage less than that which will pay for treatment costs for insurance purposes.

Table 2.4. Economic threshold infestations per field[b]

County	1971	1972	1973
Bladen	1.60	1.43	2.01
Columbus	1.60	.74	1.59
Cumberland	a	a	2.14
Edgecomb	a	a	.33
Jones	a	a	1.52
Lenoir	a	a	2.62
Nash	a	a	.62
Surry	.10	.18	.72
Wayne	.31	.36	.84
Wilson	.31	.37	.42
Program Total	.72	.63	1.17

a - not included in study in this year
b - based on data from 1971, 1972 and 1973 Tobacco Pest Management Reports
c - Thresholds are:
budworms - 5 or more larvae per plants - 1971
5 or more plants infested per 50 plants - 1972-1973
hornworms - 5 or more large larvae per 50 plants
flea beetles - aphids - when levels are rated heavy.

III. A. Benefit Measures

Net private benefits from integrated pest management programs can take three basic forms: (1) cost saving from less pesticide use, (2) increased production yields from proper use and timing of the chemicals, and (3) a decrease in long run infestation numbers from properly timed stalk destruction. All of which are ultimately translated into increased grower profits.

Cost Saving

Table 3.6 shows that in 1971 tobacco pest management farms in North Carolina experienced a cost saving estimated at $2[illegible]1 per acre ($11.28-8.77) compared with the mean of all North Carolina tobacco farms. If treatment costs are taken to be approximately $3.60 per acre, then tobacco IPM in North Carolina saved program farms about .7 of one application per acre. If it is assumed that the treatment cost for all farms remained at the $11.28 level for 1972 and 1973, then cost savings of $5.55 and $4.73, respectively would have been realized, or approximately 1.4 applications per acre.

It would be expected that insecticide use should increase as the number of pests rise. The measure used by the tobacco program in North Carolina to indicate program effectiveness in reducing pesticide use was the number of insecticidal applications per threshold report. Thus, the figure which indicates optimum pesticide use if 1.0, or one application for each threshold report. Table 3.1 summarizes the applications per threshold measure for each county during the years of the programs. Program totals show that applications per threshold decreased in each successive year. This would seem to indicate an overall success in reducing pesticide use toward the optimal level. However, certain factors should be considered before adopting this measure as a relevant indicator of program success. First of all, this ratio is dependent upon the number

Table 3.1. Average number insecticide applications per threshold report

County	1971[a]	1972[a]	1973
Bladen	2.5	1.9	1.2[a]
Columbus	2.5	3.7	1.3[a]
Cumberland	b	b	2.27[c]
Edgecomb	b	b	b
Jones	b	b	1.83[c]
Lenoir	b	b	.76
Nash	b	b	b
Surry	4.0	2.0	.7[a]
Wayne	5.3	2.3	1.1[a]
Wilson	5.3	3.5	4.8[a]
Total	3.4	2.6	2.1[d]

a - From 1973 Tobacco Pest Management Report.
b - Not available or county not in program.
c - Estimated by dividing applications by threshold reports.
d - Weighted average by acreages except for Edgecomb and Nash Counties. Figure given in 1973 Tobbaco Pest Management Report is 1.6.

of thresholds. It may be that higher pest populations such as occurred in 1973 merely raised thresholds closer to the number of treatments which a grower intended to apply. (Growers may raise treatments when pest populations rise, but at a diminishing rate.) Thus, higher pest populations and not program effects may account for the falling ratio which occurred between 1972 and 1973. A more complete measure of effects of the management program on insecticide use would have to include other things which are known to affect insecticide use such as the price of insecticides and the price of the tobacco crop.

The program totals in Table 3.1 are seasonal averages of total applications per threshold. Table 9 in the NCTPM report for 1972 indicates that in many instances there were relatively high levels of treatments during weeks of relatively few threshold reports and sometimes relatively low treatment levels during weeks of relatively many threshold reports. This tends to indicate improper timing of pesticide applications, and this timing aspect of applications may be more important than the seasonal averages in Table 3.1. Another indication of this improper timing aspect is that in some counties the ratio of applications to thresholds is less than one, which would indicate an underuse of pesticides and perhaps some loss in tobacco yield and/or quality. Surry and Lenoir Counties applied less insecticides than recommended on the average in 1973. This is not discussed or evaluated in the 1973 tobacco pest management report.

Yield Effects of Program Efforts

A yield study involving four counties in the North Carolina Tobacco Pest Management Program was made in an attempt to discover any program-related effects on tobacco yields. The results of this study are summarized in Tables 3.2 and 3.3. Random samples of fifty farms in the program and fifty farms not in the program were taken from county Agricultural Stabilization and Conservation

Table 3.2. Average yields for 1969-1973 in four sample counties for program and non-program farms

County	Year	Non-pest management farms Average yield	Pest management farms Average yield
		(pounds per allotment acre)	
Wilson	1969	2102.3	2178.9
	1970	2265.1	2350.4
	1971*	2227.6	2211.0
	1972*	2215.6	2271.9
	1973*	2306.9	2437.0
Columbus	1969	1933.1	2008.0
	1970	2107.4	2274.1
	1971*	2194.2	2291.1
	1972*	2148.0	2228.7
	1973*	2306.3	2318.1
Bladen	1969[a]	1477.6	1476.8
	1970	1964.0	1859.5
	1971*	1986.9	2028.8
	1972*	1959.3	1991.9
	1973*	2104.6	2601.4
Cumberland	1971	1983.0	2344.8
	1972	2061.5	2272.5
	1973*	1947.8	2328.5

* - Indicates the years in which the Pest Management Farms were in the Tobacco Pest Management Program.

a - Extensive hail damage in 1969 resulted in relatively low yields.

Table 3.3. Results of tests for yield effects

County	Non-pest management farms		Pest management farms
Wilson			
Years before program (1969, 1970)	2183.7	← * →	2264.7
	↕ n.s.		↕ n.s.
Years during program (1971, 1972, 1973)	2250.1	← n.s. →	2306.6
Columbus			
Years before program (1969, 1970)	2020.3	← * →	2141.0
	↕ **		↕ **
Years during program (1971, 1972, 1973)	2216.2	← n.s. →	2279.3
Bladen			
Years before program[a] (1969, 1970)	1720.8	← n.s. →	1668.1
	↕ *		↕ *
Years during program (1971, 1972, 1973)	2016.9	← n.s. →	2207.4
Cumberland			
Years before program (1971, 1972)	2022.3	← ** →	2308.6
	↕ n.s.		↕ n.s.
Year during program (1973)	1947.8	← ** →	2328.5

a - extensive hail damage in 1969

n.s.- yield difference not significant

* - yield difference significant at $\alpha = .05$ level of probability

** - yield difference significant at $\alpha = .01$ level of probability

Service (ASCS) records in Wilson, Columbus, Bladen, and Cumberland counties for the years 1969 through 1973.[1] Care was taken to include principally the same farms over the five year period so as to reduce variation between samples due to non-homogeneity of samples. Data on farm yields were recorded and later analyzed. Four types of yield differences were tested for each county[2] (see Table 3.3):

I. Years before the program, non-program farms versus years before the program, program farms

II. Years during the program, non-program farms versus years during the program, program farms

III. Non-program farms, years before the program versus non-program farms, years during the program

IV. Program farms, years before the program versus program farms, years during the program

Wilson

In Wilson County only the type I difference was significant. The fact that difference type II was not significant indicates, if anytning, that the program had an adverse effect on yields since program farms had singificantly higher yields before the program, but not after the program began.

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[1] Samples for Cumberland County were taken for 1971, 1972 and 1973 only. Data were unavailable for 1969 and 1970, however, since Cumberland was in the program in 1973 only, the two-year yield history for 1971 and 1972 is adequate.

[2] A related t test was employed as the means for testing the differences between any two average sample yields. The t statistic was computed as follows:

$$t = \frac{\bar{Y}_1 - \bar{Y}_2}{S_P^2 \left(\frac{1}{n_1} + \frac{1}{n_2}\right)}$$

where $\bar{Y}_1 - \bar{Y}_2$ is the difference between the two means

n_1, n_2 are the sample sizes

and S_P^2 is the pooled sample variance.

Columbus

In Columbus County difference type IV was highly significant, and this result taken by itself would appear very favorable to the program. However, difference type III was also highly significant, and therefore no conclusion can be drawn as to whether or not the yield increases are due to the program or are merely due to a time trend in yields on all farms. Also, the same results as in Wilson are true for differences types I and II, indicating again, if anything, a negative program effect on yields.

Bladen

The analysis of Bladen county was hampered somewhat by widespread hail damage in 1969. This resulted in very low yields for the year before the program, and the significance of differences types III and IV are attributable, in large part, to this hail damage. Differences I and II were not significant. (Note, however, that program yields were about 52 pounds lower before the program and 190 pounds higher during the program. High variability make these differences nonsignificant.)

Cumberland

Cumberland County is somewhat similar to Columbus. Difference type II is highly significant, and taking this result alone shows a positive yield effect for the program. However, difference type I is also highly significant, and again no conclusion can be made about program's effect on yields. Types III and IV were nonsignificant.

In a further effort to isolate any program effects on yields, another set of tests was made. These tests involved Wilson, Bladen and Columbus counties. In each county, the yields for the years before the program were compared to yields in each year during the program for both the program and non-program farms. In every case, the results for the program farms were identical to the results of the non-program farms. When a difference was not significant for the program farms, it was also not significant for the non-program farms. And when a difference was significant for the program farms, it was also significant for the non-program farms. Therefore, no isolation of program effects on yields was discerned, and the results of this second set of tests served to reinforce the results of the original analysis. Those results being that the North Carolina Tobacco Pest Management Program had no significant positive effect on tobacco yields.

It should be noted that the tobacco pest management program in North Carolina was not directed toward yields. The main thrust of this program was to attempt to decrease pesticide use by attempting to eliminate pesticide overuse. In this category, the program was relatively successful.

Stalk Destruction

Early stalk destruction was a major goal of this pest management program. Properly timed stalk destruction reduces overwintering hornworm and budworm populations by eliminating the food of these pest insects which are entering diapause. During the years 1971-1973 stalk destruction lagged repeatedly, yet some improvement was shown. The chief deterrant to proper stalk destruction is the time at which it is necessary. In the days immediately following harvest, the grower's primary concern is getting his harvest to market, thus plowing under stalks is of secondary concern. However, early stalk destruction can be shown to have significant long run benefits when advocated as part of a tobacco pest management program. It was estimated that proper timing of stalk destruction in 1972 could have reduced overwintering hornworm populations by up to 60 percent.[3]

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[3] North Carolina Tobacco Pest Management Program; Second Annual Report, 1972 p. 46.

An indication of the program's effectiveness in reducing undestroyed stalks can be seen by comparing the post harvest survey results over the years 1971 through 1973. In 1971, in Wayne and Wilson Counties, approximately 98% of harvested fields contained undestroyed stalks by the end of August; in 1972, approximately 35% contained undestroyed stalks at the same time, a significant reduction; in 1973, however, the percent of fields with undestroyed stalks increased to 55%, an improvement over 1971, but worse than 1972.[4]
In Columbus and Bladen Counties, significant improvement in stalk reduction was shown between 1971 and 1972/1973. However, there was no significant change between 1972 and 1973.[5]

From this evidence it can be concluded that the program has contributed significant improvement in stalk destruction timing since its beginning. Yet stalk destruction remains far from stated program objectives. Optimal stalk destruction must consider the opportunity cost of the grower's time. It may be that stalk destruction for disease but not for insect control, which must come earlier, is more economically efficient. The major unknown is the quantitative effect of stalk destruction on insects in future years. No concise data were generated by the program to evaluate this.

Pest Management Adoption

The degree of acceptance such as measured by percent of acreage scouted in a county is not a useful indicator of the benefits provided by the NCTPM program. At the outset of the program, a certain amount of "selling" was necessary to influence growers to participate in the program. Therefore, acceptance due to program benefits and acceptance due to project "salesmanship" are difficult to distinguish. In 1973, five new counties were included in the project, yet again, the amount of "selling" as compared to the amount of voluntary adoption is in doubt. In 1973 the program was offered to growers in the five original counties on a strictly voluntary basis. Participation decreased to 2684 fields from 3339 fields in 1972, a decrease in participation by 20% in the five original counties. There was a 14% decrease in acres.[6]

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[4] North Carolina Tobacco Pest Management Program; Third Annual Report, 1973 p. 19. Some of the differences are due to harvest date changes.

[5] Ibid.

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[6] Ibid., p. 4.

III. B. Farm and Public Costs

This section analyzes costs associated with the North Carolina Tobacco Pest Management Program. Attention is devoted to each of three main types of costs: (1) scouting costs (2) total program costs and (3) grower costs. Table 3.4 summarizes scout wage and travel expense data for individual counties from 1971-1973 in terms of cost per field and cost per acre. Both cost measures are included because cost per acre allows these costs to be compared to other crops on a per acre basis, while cost per field employs the basic unit (the field) used by the NCTPMP. Also, cost per field is consistent with the cost model to be presented shortly.

Scout wages and scout travel per acre fell continuously from 1971 to 1973. Wage costs fell even though wage rates rose from $2.48 per hour in 1971 to $2.76 in 1973. Changes in the work accomplished per hour and increased field size were thought to have caused the reduction in scouting costs. The next section attempts to determine what factors led to the decrease in costs other than the change in field size.

Factors Affecting Scouting Costs Per Field

An attempt was made to explain the costs of scouting specific to the North Carolina Tobacco Pest Management Program, and the results provide a surprisingly accurate model for the prediction of scouting costs related to this program. The model estimated by multiple regression takes the following form (standard errors of regression coefficients are given in parenthesis):

$$\ln C = 3.179 + \underset{(.035)}{0.941} \ln X_1 - \underset{(.030)}{0.893} \ln X_2 + \underset{(.028)}{0.089} \ln X_3 - \underset{(.030)}{0.129} X_4 + \underset{(.032)}{0.077} X_5$$

The strength of this model's accuracy is reflected in the fact that all coefficients were significantly different from zero at a level of probability

Table 3.4. Seasonal tobacco scout wage and scout travel expenses per field and per acre

County	Year	Scout wages		Scout Travel	
		$/field	$/acre	$/field	$/acre
Columbus/Bladen	1971	16.05	6.98	2.39	1.04
Columbus/Bladen	1972	11.82	5.14	1.98	0.86
Columbus	1973	13.77	4.59	3.06	1.02
Bladen	1973	14.70	6.39	3.47	1.51
Wayne/Wilson	1971	13.36	4.31	2.98	0.96
Wayne/Wilson	1972	16.21	5.23	2.17	0.70
Wayne/Wilson	1973	13.47	4.21	1.50	0.47
Surry	1971	12.90	6.45	2.58	1.29
Surry	1972	12.00	6.00	2.06	1.03
Surry	1973	10.60	5.30	1.90	0.95
Cumberland	1973	9.20	2.00	2.94	0.64
Jones	1973	14.24	3.03	3.95	0.84
Lenoir	1973	16.22	3.18	4.28	0.84
Nash	1973	11.05	2.57	3.61	0.84
Edgecombe	1973	10.50	1.50	5.86	0.30
Program Totals	1971	14.27	5.49	2.68	1.03
	1972	13.86	5.33	2.11	0.81
	1973	13.00	3.94	2.48	0.75

less than .01, and that the model explains approximately 96% of the variation in scouting costs ($R^2 = .964$). The variables are defined as:

C = total scouting cost/field/week

X_1 = wages/scout/hour

X_2 = average number of fields scouted/scout/week

X_3 = average number of acres/grower

X_4 = 1 where incentive payment is present

= 0 otherwise (normal payment scheme)

X_5 = 1 where 1972 observations are present

= 0 otherwise (1973)

Scouting costs, C, were calculated for each scout or scout pair in each program - affiliated county for the years 1972 and 1973 as follows:

$$C_i = \frac{w_i + t_i}{f_i}$$

where w_i is the average weekly wage rate for scout i, t_i is the average weekly travel expenses of scout i, and f_i is the average number of fields scouted per week by scout i. There were a total of n = 58 observations. The mean values of each variable are as follows:

$\bar{C}$ = \$ 1.54

$\bar{X}_1$ = 3.10

$\bar{X}_2$ = 96.61

$\bar{X}_3$ = 10.63

Let us look at each explanatory variable separately.

Scouts were paid by the hour with an hourly rate comensurate with their age and experience. About 50 percent of the scouts in 1972 were scouts in 1971. Scouts were expected to work 40 hours per week, and were paid overtime wages for any overtime work. As would be expected, this variable X_1 accounts for a large percentage of the variation in total scouting costs. Note that a $1.00 increase in the wage rate above the mean of $3.10 would cause scouting costs per field per week to increase by approximately $.45 with all other variables constant. A 10% increase in wage rate results in a 9.4% increase in costs.

The model shows that decreasing the scout workload, in terms of the number of fields scouted per week, by 1.0% will increase scouting costs per week by approximately 0.9%. For example, the increase in fields scouted per week from a mean of 92.1 in 1971 to 101.7 in 1972 resulted in a reduction in costs of about $.14 per field per week. This says that there is a higher marginal cost of scouting fewer fields. This study does not attempt to determine an optimum workload strategy, but two constraints that would obviously affect this workload would be a time constraint and a quality constraint. No doubt as X_2 increases past a given point, the quality of scouting would be adversely affected.

The number of acres per grower, X_3, is a variable which reflects how total scouting costs vary as the size of the farm varies. It was hypothesized that the size of farm would be related to travel expenses, i.e., on large farms it may be necessary to drive more to cover all the necessary fields. This appears to be the case, for the results imply that larger farms cost more to scout per field holding all other factors constant.

The variables X_4 and X_5 are dummy variables. In 1973 in Wilson County, three scouts were paid using an incentive payment scheme. Normally, scouts are paid by the hour, however these three individuals were paid a wage comensurate with the number of fields scouted. These three scouts scouted approximately 150 fields per man per week. The other scouts in Wilson scouted approximately 100 fields per man per week. Therefore, it was decided to place a dummy variable in the model for the scouts on this incentive plan to determine what effects, if any, the type of payment system used had. The results of the model show a significant decrease in total scouting costs where this "piece rate" payment system is used. In monetary terms, the model shows that where the incentive payment plan was used, all other things constant, there was approximately a 12% decrease in scouting costs. Using the average levels of all other variables and computing costs based on the normal payment system ($X_4 = 0$) results in a cost of approximately $1.63 per field per week. Using the same average values and including the incentive plan coefficient ($X_4 = 1$) estimates the cost at $1.43 per field per week, or a saving of about $2.40 per field during a 12-week scouting period or 12 percent.

Although no empirical study was made to determine the effects of the piece rate method of payment on the quality of scouting, the project supervisor felt there was no adverse effect on quality.

X_5 is a year effect dummy variable which indicates any significant differences in total scouting costs between the years 1972 and 1973. It's coefficient indicates that the costs of scouting in 1972 were significantly greater than scouting costs in 1973. This effect can probably be traced to various program changes which took place in 1973. Operational changes such as only surveying for pest insects (there were fewer beneficial insect surveys), reducing the number of locations visited per field (from five to four), and only counting pests when the crop was at the most susceptible stages of growth were made. These changes were instituted so that the amount of time spent in each field was reduced. Instituting these program changes resulted in a per week cost decrease from 1972 to 1973 of about 15 percent. Other variables were attempted in the regression including the number of checks per field, the number of species to be identified, the number of growers per scout, and the number of fields per grower. None of these offered significant contributions to the model.

Total Program Costs

Table 3.5 categorizes total program costs based on total dollars spent per total fields and total acres scouted. Scout costs are actual expenditures, whereas all other categories are calculated from the submitted program budget. Data was unavailable for 1971 expenditures other than scouting and total dollars per total fields and total acres. Scouting costs fell from $17 per field in 1971 to $15.62 in 1972 and $15.46 in 1973. Program costs are about equally divided between scouting, supervisory and clerical labor, professional labor and other.

It is interesting to note the total program costs per acre. The total program cost per acre for Arkansas cotton scouting programs is about $1.00 to $1.15 per acre as compared to about $17.00 per acre for the 1973 North Carolina tobacco program. Total cost per acre is no doubt a function of the size of the scouting unit. Large production units such as cotton fields appear to be more suited to IPM programs than the smaller production units such as tobacco. It is believed that the reason for the high per acre costs of this tobacco program are directly related to the problems of coordinating a pest management program with a large number of small production units. Note the large proportion of expenditures for other items besides scouts.

Grower Costs

Table 3.6 gives the estimated grower costs of insect control. The estimated cost of insecticides plus applications on all farms in North Carolina for 1971 was $11.28 per acre. In 1971 these same costs for program farms are estimated at $8.77 per acre, which implies a cost saving of $2.51 for program farms. If the non-program grower costs were the same in 1972 and 1973 as in 1971, then cost savings would have been $5.55 and $4.73, respectively. Thus, if 1971-73 are representative years there may have been an average (over years) cost saving of $4.26.

Table 3.5. Total program costs per field and per acre

Budget item	1971 $/field	 $/acre	1972 $/field	 $/acre	1973 $/field	 $/acre
Scouts[a] wages and travel expenses	17.03	6.53	15.62	6.14	15.46	4.70
Scout Supervisors			3.79	1.47	4.55	1.38
County Agents			3.44	1.32	4.36	1.32
Professional			9.76	3.75	11.33	3.44
Clerical			2.50	0.96	3.73	1.13
Data Processing			2.16	0.83	3.30	1.10
Environmental Monitoring			1.14	0.44	0.33	0.10
Other[c]			7.50	2.89	13.07	3.96
Program Totals	38.76[b]	14.91[b]	45.91	17.80	56.13	17.13

a - These 6 costs are based on actual expenditures. All other cost are based on budgeted amounts.

b - These program totals are calculated using total actual expenditures per total program acres. The other program totals are simply sums of the individual budget items.

c - This item includes funds budgeted for ongoing research, regulator personnel, supplies, insect collection and identification, Experiment station administration and extension administration.

Table 3.6. Estimated tobacco grower costs for insect control

	Year		
	1971	1972	1973
Average Number of Applications per Acre on Program Farms	2.40	1.57	1.90
Insecticide Cost/Acre[a]	$3.25	$2.12	$2.18
Application Cost/Acre[b]	5.52	3.61	4.37
Total	8.77	5.73	6.55
Estimated Cost on all North Carolina Farms	$11.28	n.a.	n.a.

a - weighted average retail price of materials used per application at recommended rates; 1971 - $1.35, 1972 - $1.35, 1973 - $1.15. Based on estimates and price lists of three North Carolina formulators.

b - custom rate of $2.30 is the mean of a survey of 53 custom application in North Carolina in 1973, H. Liner, NCSU.

c - based on estimate of 2.0 pounds of materials or 3.09 applications at above prices. The 2.0 pounds per acre of tobacco estimate is from the 1971 USDA pesticide survey.

n.a. - not available

III. C. Environmental Effects of Program

A major part of the program effort was to reduce insecticide contamination of non-target species. In 1971, 7 beneficial species were sampled at 10 sites inside and 10 sites outside the program area. In 1972, 17 of the sites were within the management study area and 12 were in an adjacent area. Tiger beetles were also collected at 14 farms inside and outside program area I in 1972, and 20 sites inside and 5 sites outside program area II in 1973. Data on the residue insecticides in the sample areas are given in the tobacco pest management reports. The basic conclusion was (p. 24, 1973 report). "Our basic conclusion... is that only traces of currently used chemical pesticides are found in samples taken since 1971. This would logically indicate that presently used pesticides do not create environmental residue problems at the rates and numbers of applications used on tobacco. ....with the exception of methomyl, those residues found represent pesticide usage from an era preceding the pest management program and do not serve as a means of evaluating the contribution of the pest management project in reducing environmental impact."

Tests of mortality effects of insecticides on the beneficial tiger beetle can be made. Table 3.7 shows mean beetle trappings per field for 1972 and 1973.

Table 3.7. Mean tiger beetles per field

Year	Inside	Outside
1972	86.5	73.9
1973	101.8	77.8

Comparison of the means of beetles caught inside and outside the program areas for 1972 and 1973 shows those differences to be insignificant at the .05 level of probability. The ability of these tests to show significant differences in these means was hampered somewhat by very large estimates of variance, especially in the case of 1973. The economic benefit of saving about 20 percent of the tiger beetles in an area by reduced insecticide treatments is not known. The main point is that it was found that tiger beetles can be used as an indicator of some of the environmental impact of changes in tobacco insecticide use.

A more general measure of the environmental gains from the program is the change in quantity of insecticides not used as a result of the program. Table 3.8 shows the county and program mean level of insecticide applications and pounds of active ingredients. The program means of 1.55 lbs. for 1971, 1.13 lbs. for 1972 and 1.42 lbs. for 1973 are all substantially below the USDA estimate of 2.0 pounds for all North Carolina tobacco farms in 1971. Unpublished data from the 1971 USDA survey indicates that average use in Surry and Edgecombe counties was 2.03 and 5.63 pounds of insecticides per acre of tobacco grown. The Surry County figure is about 4.6 times as large as that on the program farms. Program insecticide use in Edgecombe County was not compiled.

Scouting may also assist some growers in not applying insecticides for an entire season. Data was incomplete in 1971, but in 1972,14.5 percent and in 1973, 22 percent of the program acreage was not treated at all. This is about the same as the 19 percent figure for all North Carolina tobacco acreage in 1971 which was a less severe pest year than 1973.

Table 3.8: Insecticide applications and pounds per acre per year on program farms by counties[d]

County	1971 app.	 lbs.[c]	1972 app.	 lbs.[c]	1973 app.	 lbs.[c]
Bladen	4.0	2.68	2.74	1.99	2.52	1.79
Columbus	4.0	2.68	2.57	1.86	2.12	1.36
Cumberland	a		a		4.86	2.58
Edgecombe	a		a		b	b
Jones	a		a		2.78	1.99
Lenoir	a		a		2.00	1.42
Nash	a		a		b	b
Surry	.4	.44	.39	.39	.53	.27
Wayne	1.6	.99	.90	.63	.92	.70
Wilson	1.6	.99	1.37	.96	2.00	2.05
Program Totals	2.4	1.55	1.57	1.13	1.90	1.42[e]

a - not included in study in this year

b - data not collected

c - estimated using weighted average of program grower use of material types times recommended rates per application of active ingredients.

d - application rates from North Carolina Tobacco Pest Management, 1st, 2nd and 3rd Annual Reports, 1971, 1972, 1973, Raleigh, North Carolina

e - field weighted average

IV. Projections and Limitations

A. Limitations

The major obstructions in expanded tobacco insect scouting to other parts of North Carolina or other states are the high cost of scouting, small fields and absence of yield increases from better insecticide timing.

Whereas cotton or soybean scouting can be limited to three points in a 20-40 acre field, tobacco inspection for pests requires about one inspection point per acre. Also, tobacco scouting in the 1971-1973 program was for 12 weeks per season. Cotton scouting may only be needed for 10 weeks and soybean scouting for only about 3 weeks per season. This led to average scouting plus supervisory costs per acre of $6.52 in 1971 to $6.08 in 1973. Scouting costs without supervisory costs for the new counties in 1973 were $2.88 per acre. It probably is reasonable to assume some additional learning will occur from repetitive tasks such as insect scouting. Thus, it may not be unreasonable to project scouting plus supervisory costs of about $3.50-$4.00 per acre at present wage rates.

Direct scouting costs of $3.50 per acre are slightly less than the estimated average insecticide savings of $4.26 per acre. However, total average program costs were $17.13 per acre in 1973. Of this cost overhead was about $11.00 per acre based on a program of 11,350 acres. Thus, to have scouting plus overhead costs to be less than $4.26 would necessitate a program for which overhead costs were $.76 per acre or less or about 165,000 acres. Although this is not unreasonable (this is about 45 percent of present acreages) it would be a major undertaking.

It probably would be difficult to promote this program on a voluntary basis as merely a program to save about 4 to 5 dollars per acre for growers. County agents would be reluctant to use their time on a program that has no yield or quality improvement objectives. In extending the program to the remainder of North Carolina there would be additional costs per acre in that field sizes across the state are smaller on the average than for the program counties. The exact amount of this cost is not known because average field size is not known for the state, but it is believed to be smaller because farm size in acres is smaller. There would be a small reduction in travel cost in costs per field as indicated by the cost model. That is going from an average size farm of 11.9 acres to the state average of 7.7 acres results in lower costs per field of about 5 percent.

Limitations of the stalk destruction program are obvious in that individual growers do not capture all the area-wide benefits in reduced insect numbers. This is not the case for disease control and nematode control. These pests are less mobile, growers can capture more of the returns, and we will probably see continued efforts to destroy stalks for disease control, but not within one week for hornworm control.

B. Projections and indirect benefits

Regardless of whether or not public funds continue to be used for tobacco pest management, some indirect benefits have developed. Area-wide data on insecticide use, insecticide materials used, tobacco varieties grown and field size have been collected for research studies. Pesticide residue monitoring data is available. There has been sizeable research data collected on beneficial and harmful insects by areas. Thus, the program has assisted research.

The tobacco program has trained scouts and tobacco growers about insect thresholds. These growers can apply these principles to other crops and insects as well. About 1000 growers and 10 county agents received direct training in application of insect thresholds.

The greatest promise for tobacco pest management may be in a combination of nematode, disease and insect control. The usual arguments here are that scouts can be hired year around to inspect fields for several disorders thereby lowering scouting costs. However, this seems to depend upon the costs of hiring individuals well enough trained to detect several types of pathogens, insects and nematodes. A more positive argument may be that a multi-disciplined consulting service may be able to sell advice on resistant varieties, fertilization, pesticide purchase and use for fairly small units such as 5 acre tobacco fields. Growers may find these profitable in terms of additional yield and quality as well as reduced pesticide use.

Yield and quality improvements have not been part of the tobacco pest management program. A very small improvement in crop not lost to insects, diseases or nematodes will justify a large expenditure of pest management resources. Future work should be devoted to showing yield changes from pest management practices.

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